COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

May, 1948

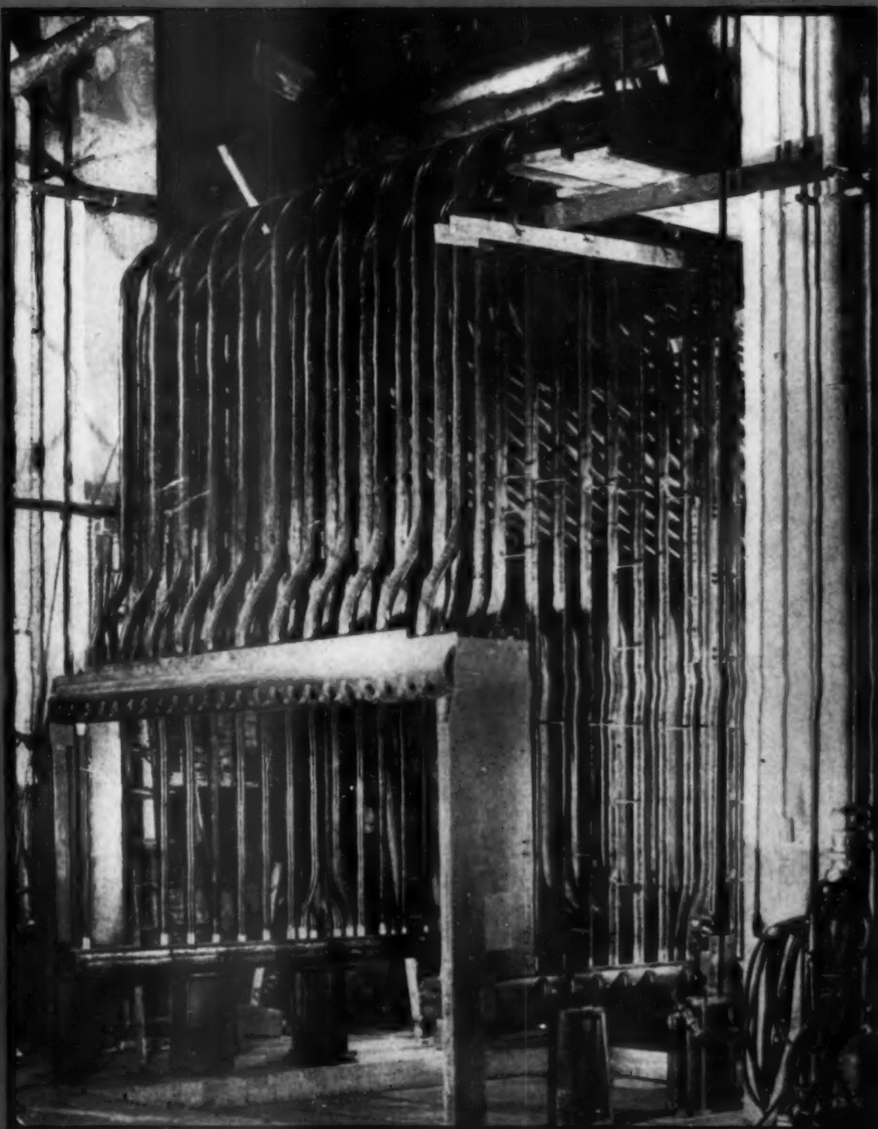

Photo by H. R. Towse

Modern small boiler unit in course of construction at Sunshine Biscuit Company, Long Island City, N. Y.

CORROSION:

Its Effect in Boiler Systems—Part 1 ▶

The Selection of Mechanical Draft Fans ▶

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DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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FOR MAY 1948

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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EDITORIAL

Pulverized Coal Anniversary

A high spot of the forthcoming A.S.M.E. Semi-Annual Meeting in Milwaukee during the first week in June will be the session on pulverized coal firing, its early development and its present status.

It is most appropriate that such a program be scheduled for a meeting in Milwaukee, as it was here that the first commercially successful application of pulverized coal firing to power boilers at the Oneida Street Station was carried out just thirty years ago. Two years later *Lakeside*, the first large central station designed for the exclusive use of pulverized coal was placed in service, and established a new record in performance which it held for several years. Later its sister station, *Port Washington* established and held for many years a still better record. The boilers in *Lakeside* represented a forward step in size and were forerunners of the huge steam generating units which pulverized coal firing was to make possible in the years to come. Vast progress has been made in this method of firing during the intervening years, but the basic work was accomplished in the early tests at Milwaukee.

Regretfully, some of the pioneers in this memorable work, such as Henry Kreisinger and John Anderson, have now passed on, but others, representing the power company, the equipment manufacturers and the Bureau of Mines, who were identified with the development, are still active and will contribute to the program. The session, as well as the accompanying exhibit, should prove both interesting and informative

Opportunities for Engineering Graduates in the Power Field

This is the season when seniors in engineering schools are making their decisions as to the lines in their chosen profession which they expect to follow. While subsequent circumstances or changing conditions sometimes serve to divert the selected course, in many cases it will be charted by the initial job following graduation.

Seldom have opportunities for mechanical and electrical engineering graduates appeared more promising, notwithstanding rumblings of a pending draft. This is particularly true of the power field in which increasing demands brought about by new industrial, commercial and residential applications of electricity point to continued growth over a considerable period. This is reliably estimated to result in the installation of at least 40 million kilowatts of new capacity during the next ten years. Such demand is strengthened by the trend toward automatic operation, or greater horsepower per worker, to partially compensate for ever increasing wage levels in most commercial lines.

The power industry represents a broad field, comprising design, production and sales, whether applied to the manufacture of equipment, the generation of power by steam, hydro or gas, its transmission, or applications involving innumerable processes and power consuming devices. There are also new economic problems introduced by increasing cost of fuel and scarcity in supply of certain types, as well as an entirely new industry, the synthetic production of liquid fuels, which commands the services of both chemically trained men and mechanical engineers.

These represent only a few of the avenues open to the June graduate who feels inclined toward embarking on a career in the power field, but they should suffice to suggest the broad opportunities offered.

Power on the Pacific Coast

Many are accustomed to think of the Pacific Coast region as being supplied chiefly with hydro power—an impression strengthened by the publicity accorded federal power projects in the Northwest and by the power shortage in California during the past winter and early spring, because of drought. However, it would appear that in this state over thirty-five per cent of the present installed capacity is steam—a figure that will be increased to at least forty per cent in the next two or three years when capacity now on order is in operation. This, of course, must not be confused with the Northwest which is not favored with abundant gas and oil as is California.

Since most of the economically developable sites have been put to use in California, steam rather than hydro is expected to predominate in further projected capacity designed to meet a continuously growing demand which has been authoritatively estimated to double by 1965.

CORROSION:

Its Effect in Boiler Systems—Part 1

Part I of this article discusses briefly the theories of corrosion, then proceeds to describe the action of oxygen in the boiler system, its removal by mechanical and chemical means, and protection against its action in idle boilers. Part II, to appear in the June issue, will deal with carbon dioxide, ammonia, hydrogen sulfide, acidity and certain physical factors.

By ROBERT L. REED
Chemical Engineer, W. H. and L. D. Betz

THE majority of engineers have cognizance of the corrosion potential always existing in power plant operation. Extensive boiler repairs, condemnation of steam generating equipment, expensive feed line, steam line and returned condensate line replacements, as well as costly plant shutdowns, frequently can be attributed to wastage of metal due to corrosion. The purpose of this article is to present the more widely accepted theories relative to the mechanism of corrosion, the nature of corrosive action as usually manifested in boiler systems and to discuss proper preventive measures in general.

Mechanism of Corrosion

A brief discussion of theories concerning corrosion fundamentals is fitting at this time, although space limitation restricts a truly detailed discussion of this extensive and controversial subject. Iron will be the metal principally considered in examples illustrated inasmuch as some form of that metal is most frequently utilized in constructing steam generators and auxiliary equipment. However, other metals behave in a quite similar manner.

Most metals exhibit a tendency to dissolve when exposed to water or an aqueous solution and, in the majority of cases, the phenomenon can be explained in terms of an "electrochemical" reaction. This transformation depends upon many conditions and the type of metal represents one of the most outstanding influencing factors. To judge the potential of various metals to go into solution, authorities on corrosion employ the "Electrochemical Series," with Table A showing the arrangement of the more commonly encountered metals based on determinations under certain controlled conditions.

Reference to the table reveals that the elements listed fall into two classifications, namely electronegative and electropositive, and the element hydrogen stands between the two groups. With respect to the electronegative group, the metals tend to dissolve in the solution as positively charged ions while leaving the parent metal negative. The electropositive elements, on the other hand, do not possess the dissolving tendency, but rather metal ions from the solution are inclined to plate out upon the metal surface and thus render the surface positive. Consequently, the exchange of electrically charged particles upsets solution equilibrium, so an equivalent number of ions of some other element must be displaced.

TABLE A—ELECTROCHEMICAL SERIES

	Element	Reference Ion
Electronegative	Aluminum	Al^{+++}
	Zinc	Zn^{++}
	Chromium	Cr^{++}
	Chromium	Cr^{+++}
	Iron	Fe^{++}
	Cadmium	Cd^{++}
	Nickel	Ni^{++}
	Tin	Sn^{++}
	Lead	Pb^{++}
	Iron	Fe^{+++}
	Hydrogen	H^{+}
Electropositive	Antimony	Sb^{+++}
	Copper	Cu^{++}
	Copper	Cu^{++}
	Silver	Ag^{+}
	Mercury	Hg^{++}
	Gold	Au^{+++}

Immersion of iron or any metal in a nonoxidizing aqueous solution induces displacement of hydrogen standing between the electronegative and electropositive groups, with the hydrogen being obtained from the dissociation of H^+ and OH^- ions constituting water. Such an atomic-ionic exchange can be illustrated as:

$$\underset{\text{Atomic}}{Fe^{\circ}} + \underset{\text{Ionic}}{2H^{+}} = \underset{\text{Ionic}}{Fe^{++}} + \underset{\text{Atomic}}{2H^{\circ}}$$

Fig. 1, showing iron in contact with water diagrammatically illustrates the manner in which iron displaces hydrogen. The metal (Fe) dissolves, acquires a positive

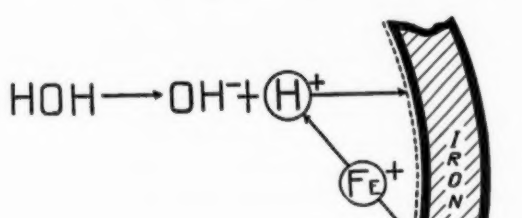

Fig. 1—Manner in which iron displaces hydrogen

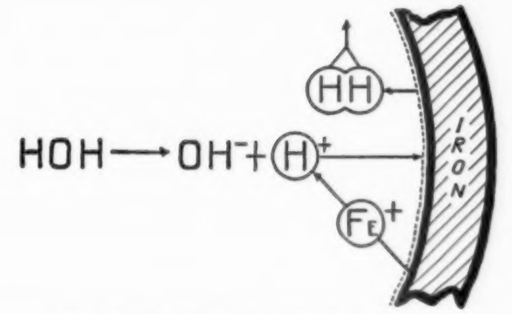

Fig. 2—Formation of hydrogen film

charge and replaces the similarly positively charged hydrogen (H) ion which migrates to the metal surface, thus creating a stifling film. Although the diagram indicates the transformation of iron into solution and plating out of hydrogen takes place at one point only, the action can occur universally over the entire area of the metal. Such displacement would continue until electrochemical neutrality was established; that is, until the tendency of the metal to go into solution balances the potential for the positive ion to plate out. The superficial film thus produced upon the metal tends to retard further corrosive action by virtue of the protective coating separating the iron and solution. The shielding effect of the hydrogen film formed will remain dominant as long as the film continues intact. However, the actions of various factors present will result in film destruction, as discussed further in this article.

In a nonoxidizing solution, two hydrogen atoms can combine to form molecular hydrogen gas. Fig. 2 illustrates the formation of the hydrogen film with hydrogen gas subsequently evolved. If this hydrogen leaves the surface, the opportunity is thus afforded for additional iron to go into solution and the reaction to progress.

Reactions involved, following solution of the iron, depend upon the environment, but for the sake of simplicity the reaction can be expressed as:

$$\underset{\text{Iron}}{Fe^{++}} + \underset{\text{Hydroxyl ions}}{2(OH)} = \underset{\text{Ferrous hydroxide}}{Fe(OH)_2}$$

That is, as the hydrogen becomes plated out, the hydroxyl (OH) ion with which the hydrogen was combined originally reacts with the soluble iron ions to form ferrous hydroxide. This action would proceed until such time that the solution became saturated with ferrous hydroxide, with the required interval depending upon the active acidity or alkalinity of the aqueous solution. Further oxidation converts the ferrous salt to ferric for the formation of insoluble ferric hydroxide, $Fe(OH)_3$ (commonly termed iron rust). Deposition of such corrosion products upon the metal surfaces may act as a barrier to retard further corrosive attack, but then again the nature of deposit and the environment might accelerate corrosion.

Dissolved Oxygen

Sources of Oxygen. Oxygen is the principal gas inducing corrosive attack, although the presence of this gas is not essential for all forms of corrosion to progress. Surface waters are generally saturated with dissolved oxygen, but pollution in some surface supplies might effect partial or complete oxygen reduction through oxidation reactions with organic impurities. On the other hand, waters procured from wells, especially deep wells generally contain little, if any, oxygen. In some cases where aeration systems are installed for removal of certain dissolved gases, such as carbon dioxide and hydrogen sulfide, the water becomes saturated with oxygen.

Dissolved oxygen can be introduced into boiler systems not only by the raw makeup supply, but also through air infiltration into the condensate system through leaks. Oxygen contamination will result with leakage at pumps, water seals on centrifugal pumps, shaft glands on steam turbines, radiator valves or any points where atmospheric pressure is exerted from the outside and a partial vacuum exists on the inside. Frequently, the take-off pipe from a condensate receiving tank is located so high that air is drawn periodically into the system when the water level

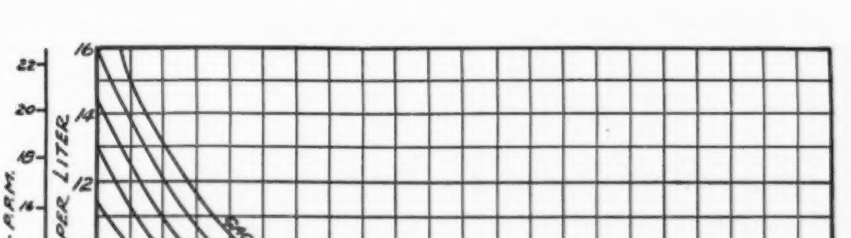

Fig. 3—Chart showing solubility of dissolved oxygen

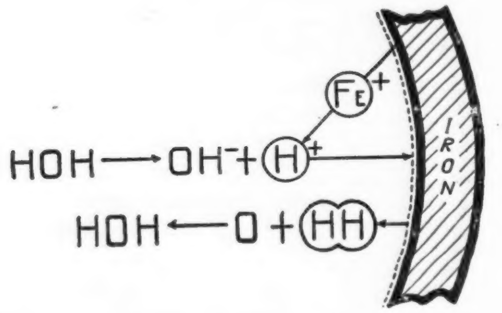

Fig. 4—Dissolved oxygen-hydrogen reaction illustrated

drops, especially when the condensate returns spasmodically.

An inspection of Fig. 3 reveals the solubility of dissolved oxygen at various common temperatures and pressures, although various constituents present in an aqueous solution can influence the quantity of oxygen actually absorbed. For example, it has been shown that the solubility of oxygen is greater with distilled water than with water of higher solids content under identical pressure and temperature conditions. Increased agitation, exposure of a greater area and extension of contact time allows larger quantities of oxygen to become dissolved in a solution.

Oxygen dissolved in the boiler feedwater is liberated with increase in temperature and is free to cause wastage of the metal. Heat-exchange equipment and economizers are most susceptible to attack from this aggressive gas. In certain type boilers, the tube bank through which only feedwater passes and which normally does not contain concentrated boiler water essentially constitutes an economizer section also and will be readily attacked by oxygen. Although corrosion within steam generators is generally most prevalent above the water line, the impression frequently held by plant operators that oxygen does not attack below the water level is erroneous. Air bubbles containing oxygen can be localized and adhered to the metal by oil or debris in any section of the boiler, thus causing pitting under water in such areas.

Normally, however, a large percentage of oxygen liberation within steam generators occurs immediately when the feedwater reaches the increased pressure and temperature conditions encountered in boiler operation, thus accounting for the fact that most severe oxygen corrosion within boilers occurs usually in the vicinity of the feed line discharge and at the water level. In addition, a portion of the corroding gas will volatilize with the steam to cause corrosion and ultimate failure of steam lines as well as condensate lines. This latter condition is true especially when the steam take-off is located in the same drum as the feedwater discharge and when steam purification operates on the principle of scrubbing with incoming boiler feedwater.

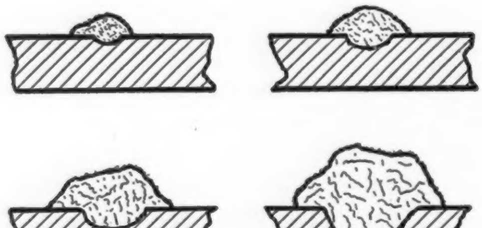

Fig. 5—Various stages of pitting

ACTION OF OXYGEN. Dissolved oxygen present in the solution destroys the protective hydrogen film by uniting chemically with the hydrogen to form water, thus allowing the surface of the metal to again become available for hydrogen liberation. For simplicity, the dissolved oxygen-hydrogen reaction has been diagrammatically illustrated by Fig. 4. The tendency for any ferrous hydroxide formed to effect stifling by the development of equilibrium conditions is offset by oxygen combining with the compound to form insoluble ferric hydroxide, in accord with the reaction:

$$\underset{\text{Ferrous hydroxide}}{4Fe(OH)_2} + \underset{\text{Oxygen}}{O_2} + \underset{\text{Water}}{2H_2O} = \underset{\text{Ferric hydroxide}}{4Fe(OH)_3}$$

Generally, oxygen produces easily identified corrosion in the form of small pits or depressions, with active pitting being manifested as a hard crust under which would exist black magnetic oxide of iron (Fe_3O_4). Various stages of pitting progression are illustrated diagrammatically by Fig. 5. As corrosive attack continues, the pit usually increases, not only in area but also in depth, and the nodule of corrosion products becomes enlarged. Of course, the detrimental effect of corrosion is more severe with oxygen inducing localized corrosion in the nature of pits than would be the case if the gas brought about general metal wastage at the same rate over a large area. The centralization of corrosion through pits permits deeper penetration of the metal and, therefore, more rapid failure takes place at the attacked areas. Fig. 6 represents a 3-in. longitudinal section of an 8-in. boiler feed line and shows clearly the severity of attack induced by oxygen. Numerous deep pits are prominent even in the small area pictured. In fact, the pits have penetrated completely the pipe wall at two points and thereby caused failure.

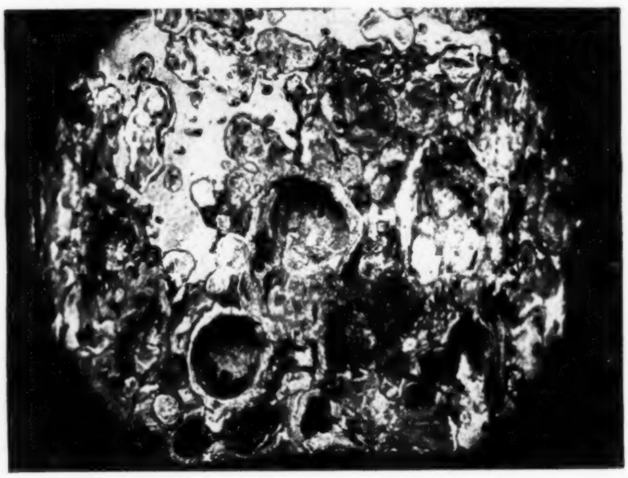

Fig. 6—Showing oxygen attack on section of feed line

In the study of corrosion problems and examination of test specimens, the actual measurement of the depths of individual pits, as can be done by microscopic methods, is of greater importance than the calculation of corrosion penetration in inches per year from weight loss data. In

some cases, a treatment may be used that will reduce materially the general weight loss of corrosion specimens and thereby reduce the calculated value of inches penetration per year. However, such treatment might provide protection over 90 per cent of the exposed area, but concentrate corrosive tendencies over the remaining 10 per cent of the surface in the form of deep pitting, with the depths of pits many times exceeding the penetration calculated simply from weight loss data.

Mechanical Oxygen Removal. Since oxygen is the constituent most frequently promoting corrosion, complete removal of the gas from all boiler systems represents the most logical corrective step. This process involves the combination of mechanical and chemical factors.

TABLE B—SATURATION TEMPERATURES AT VARIOUS BACK PRESSURES

Back Pressure, Psi Gage	Boiling or Saturation Temperature, F	Back Pressure, Psi Gage	Boiling or Saturation Temperature, F
0	212	5	227
1	215	6	230
2	218	8	235
3	222	10	239
4	224	15	250

Conventional type heaters fall into three classifications, namely, closed, open and deaerating. In the closed type, dissolved gases are actually expelled from solution, but no method of venting is possible. As previously pointed out, any liberated gases must be permitted to escape to

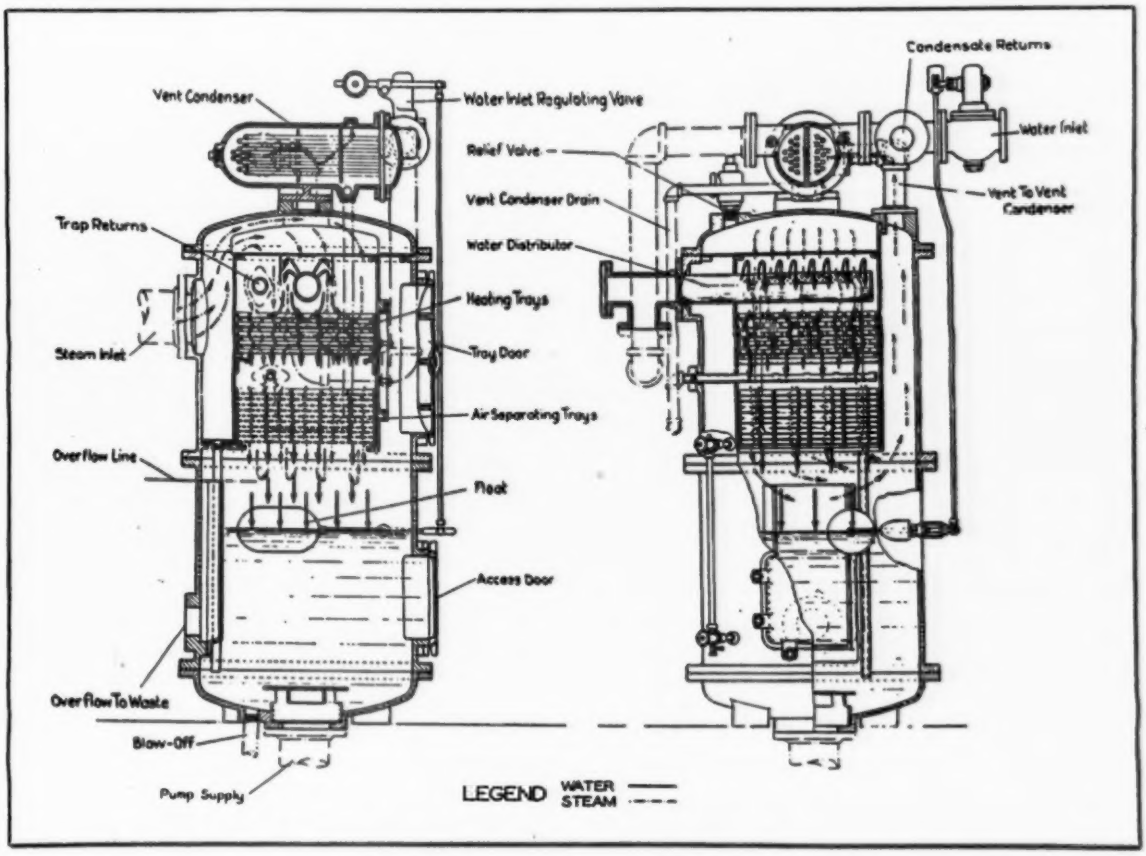

Fig. 7—Tray-type deaerating heater

Henry's Law states that the concentration of a dissolved gas in a solution is directly proportional to the partial pressure of that gas in the surrounding atmosphere. Removal of oxygen can be obtained, therefore, by reducing the concentration (or partial pressure) of oxygen in contact with the water undergoing treatment. Reduction of oxygen by mechanical deaeration operates on the principle of elevating the water temperature to the boiling point for the pressure at which the process is conducted, together with free venting from the system of the mixture containing steam and liberated gases. Saturation temperatures for various back pressures can be determined readily from the data incorporated in Table B. For the most efficient removal of oxygen, it is also necessary to employ equipment designed for intimate mixture of the water and scrubbing steam.

the atmosphere, so the absence of a vent with a closed heater allows corrosive gases to remain in the system. Open heaters usually provide means for spraying water through the steam which then falls directly into the storage section, while expelled gases escape through a vent. Oxygen reduction to approximately 0.1–0.3 cc per liter (by the Winkler method of oxygen determination) can be obtained easily with an efficiently operated unit. However, this type heater is not designed generally to effect as intimate a mixture between steam and water as in the case with a deaerating heater, thus not providing as high a percentage of gas removal.

The two major types of deaerating units (tray and atomizing) are designed especially to achieve oxygen reduction to as low as 0.001–0.003 cc per liter through agitation and intimate contact of steam and water. The

tray-type deaerating heater, as illustrated by Fig. 7, cascades water over trays arranged in a staggered or serpentine fashion. Steam introduced passes either with or in a counter direction to the flow of water. Positive distribution which allows intimatecontact is the most outstanding design factor affecting efficient gas removal. Another point of distinction between a conventional open heater and a deaerating type is the use of a vent condenser as an integral section of a deaerating heater. The heat recovery secured with the use of a vent condenser permits a larger amount of steam to be vented from the deaerating section without heat loss. While tray-type heaters are more efficient from a thermodynamic standpoint, they should not be used with waters likely to cause tray deposits. Waters relatively high in bicarbonate hardness

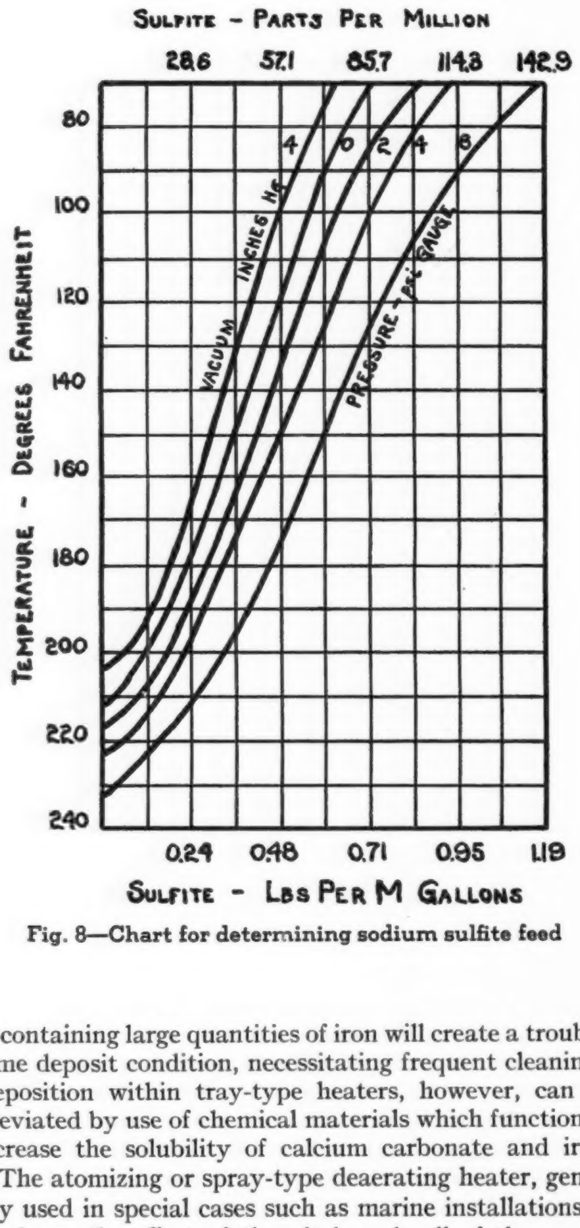

Fig. 8—Chart for determining sodium sulfite feed

or containing large quantities of iron will create a troublesome deposit condition, necessitating frequent cleanings. Deposition within tray-type heaters, however, can be alleviated by use of chemical materials which function to increase the solubility of calcium carbonate and iron.

The atomizing or spray-type deaerating heater, generally used in special cases such as marine installations to eliminate the effect of the pitch and roll of the vessel, heats the water to practically the temperature of the saturated steam by spraying water in direct contact with the steam. A high velocity steam jet atomizes the water to a mist, thus allowing a large contact surface between the water and steam. Although the atomizing jets are necessarily small in area, the opportunity for calcium carbonate or iron deposition to occur is not critical. Accordingly, such a unit is preferable in cases of high feedwater hardnesses or when the influent water contains a relatively high iron content.

The feed of sulfuric acid or zeolite softening on the acid cycle will elevate the carbon dioxide content of the make-up and thereby render the water more corrosive in nature. With the tray-type heater, frequent replacement of the equipment would be required unless constructed of expensive, corrosive-resistant materials. The use of an atomizing-type deaerator is preferred in applications with corrosive waters inasmuch as internal parts contacting the corrosive solution can be replaced readily or may be fabricated with materials such as monel metal or stainless steel. Experience has indicated stability of atomizing deaerators constructed for corrosive waters in cases where considerable costly failure would have occurred if the tray design had been applied.

Oxygen Reduction by Other Means

In addition to the conventional types of heaters discussed, vented receiving tanks or hotwells can provide a means for oxygen reduction by bleeding in steam to elevate the temperature, although the effectiveness of oxygen removal will not approach that possible with heaters designed specially for the purpose. Vacuum deaerators are available for reduction of dissolved gases from cold water and a well-designed single-stage unit permits oxygen removal to approximately 0.2 cc per liter. Wooden slats in an evacuating chamber break up the water flow to allow maximum release of dissolved gases, with a sufficiently high unit being required to provide a head exceeding the vacuum established by motor-driven vacuum pumps or by steam jet ejectors.

Obviously, adequate venting is an important requirement for mechanical reduction of oxygen, whether the process involves an open- or a deaerating-type heater. Plant personnel frequently become concerned when observing vapor escaping to the atmpsphere and believe the practice represents waste of valuable heat. From a monetary standpoint, however, it is more economical to expend the small amount of steam required for maximum gas removal than to allow the corrosive gases to enter the boiler feedwater system. Exhaust steam supplies the thermal requirements for efficient heater operation in the majority of cases, so the process actually provides a use for heat normally wasted. In fact, each 11-deg F rise of feedwater temperature attained with the use of exhaust steam results in a fuel savings of approximately one per cent. The maintenance of saturation conditions or temperature at the boiling point is so critical that, in cases where ample exhaust steam is not available, a thermostatic or pressure-control valve should be installed for the purpose of bleeding live steam into the heating section whenever a drop below saturation temperature occurs. This practice will not represent a monetary loss, however, since most of the heat in the steam will return to the boiler, except for slight radiation and thermodynamic losses.

Chemical Oxygen Removal. Mechancal deaeration is only the first step toward providing a feedwater completely void of oxygen, inasmuch as the traces of oxygen which remain in solution even following efficient heater

operation may still result in appreciable corrosion. It should be remembered that the Winkler method of determining dissolved oxygen can be considered accurate to approximately 0.035 cc per liter, so "zero" oxygen by this test does not mean necessarily absolute absence of oxygen. Actual operation has shown that as little as 0.01 cc per liter of oxygen has created a corrosive environment. Therefore, the supplemental feed of a chemical deaerant is required to remove completely the last traces of oxygen.

Oxygen Scavenging

Sodium sulfite is the chemical agent favored as an oxygen scavenger due to low costs, ease in handling and its nonscale-forming nature. The oxygen-reducing property is a chemical reaction whereby the material unites with the gas to form soluble sodium sulfate. That is:

$$\underset{\text{Sodium sulfite}}{2Na_2SO_3} + \underset{\text{Oxygen}}{O_2} = \underset{\text{Sodium sulfate}}{2Na_2SO_4}$$

The removal of 1.0 ppm dissolved oxygen demands theoretically 7.88 ppm of chemically pure sodium sulfite. However, use of a technical grade of the deaerant (approximately 90 per cent pure) combined with handling and blowdown losses as encountered in actual plant operation usually necessitates the feed of approximately 10 lb of sodium sulfite for each pound of oxygen. Based on that empirical amount, the approximate average quantities of sodium sulfite at various temperatures and heater pressures can be determined from the graph (Fig. 8). Regardless of theoretical requirements, a positive control over the feed can be attained only through a simple daily test of the boiler water, with the feed of sodium sulfite consistently regulated to develop residual sulfite concentrations in the boiler waters.

Preferably, sodium sulfite should be injected directly and continuously to the storage section of the open or deaerating heater, or to the suction side of the boiler feed pump. This method allows retention time for the oxygen-sulfite reaction which does not normally take place instantaneously. In some types of boiler installation, the continuous feeding of sulfite to the feedwater is a "must," while some small plants can combat oxygen successfully with an intermittent feeding arrangement, providing residual concentrations in the boiler water are maintained sufficiently high.

Other forms of oxygen deactivators and deaerants have been employed in various plants, some with and some without success. Organic colloids, although designed primarily for sludge conditioning, possess also the power of reducing the aggressiveness of oxygen. Certain organic blends of treatment capitalize on this advantage to some extent for prevention of corrosion problems in economizers and heat-exchangers.

Protection of Idle Boilers. The positive circulation of water within operating boilers affords uniform distribution of the chemical treatment, but with idle boilers the absence of circulation permits the likelihood of improper protection of all areas. Although dry storage of inactive boilers is preferred, operating conditions frequently necessitate a filled, standby boiler. In such cases, the unit should be taken off the line, properly cleaned, inspected for tight feedwater and steam connections, and then filled to the normal operating level. Following a short and light steaming period vented to the atmosphere to dispel dissolved gases, the boiler should be filled completely and all connections closed tightly. Sufficient sodium sulfite should be added during the final filling period in order to develop a residual value above 100 ppm, with 1.0 lb of sulfite per thousand gallons of feedwater contained in the steam generator being satisfactory in the majority of cases. Introduction of the chemical oxygen scavenger will not constitute a problem if a chemical feed line directly to the boiler is available. Otherwise, the material must be introduced into the unit through a manhole before final closing or by "shot" feeding to the feedwater during filling. In addition to sodium sulfite, caustic soda should be introduced for a phenolphthalein alkalinity concentration in excess of 400 ppm if the alkalinity does not develop naturally. Tests should be conducted once per week to assure the constant maintenance of adequate protective concentrations of sulfite and caustic. In some instances, chromate has found application as a protective agent for idle boilers.

(Continued in the June issue)

Steam-Electric Power in Spain

International difficulties with regard to Spain have been responsible for its not having taken part in several recent conventions or meetings, for which reason certain information regarding its fuel production and steam power activities has not been published abroad.

Bituminous coal, anthracite and lignite are all mined in Spain. Prior to the Spanish Civil War the average annual production was 6.5 million tons of bituminous coal, about 600,000 tons of anthracite and 300,000 tons of lignite. However, during the height of the fighting in 1937 the production fell, respectively, to 2 million tons, 400,000 tons and 200,000 tons. But nine years later, in the course of the country's restoration under the government of General Franco, the production was stepped up to 9.2 million tons of bituminous coal, 1,500,000 tons of anthracite and 1,300,000 tons of lignite.

This means that the total production increased some 62 per cent over that of pre-war output. Further increase is anticipated mainly from the large lignite deposits to which mechanization on a large scale will be applied as a result of studies now being made in collaboration with certain North American companies.

The installed capacity of steam-electric power stations, which represents about 30 per cent of the total power, increased from 250,000 kw in 1930 to 410,000 kw in 1946. Projects for new steam stations were somewhat hampered by conditions resulting from World War II, but those now under construction will aggregate close to 500,000 kw capacity. Among these the four stations of Empresa Nacional "Calvo Sotelo" and Empresa Nacional de Electricidad are outstanding and account for a total of 257,000 kw. The Ponferrada and Puertollano stations are being equipped with American-built medium-pressure boilers and the Escatron Station with C.E. high-pressure boilers. If we add others that are now under consideration, the total will reach about 900,000 kw of new steam station capacity.

Saturnio Alverez
Industrial Engineer, Madrid

The Selection of Mechanical Draft Fans*

BY A. P. DARLINGTON
American Blower Corp.

Only the two principal fan applications in the steam generating station, namely, forced and induced draft, are here considered, and no attempt is made to discuss fan design. Since the requirements of each are so different they are dealt with separately.

THE induced-draft specification with its varying temperature, varying system pressure, type of firing, which influences the variable "character-quantity" of fly-ash in the case of coal-fired units and the varying steam loading, demands the greater attention. It should be definitely understood, however, that the fanmaker is not and cannot be responsible for the duty specified. These requirements, such as pounds of gas, density, temperature and pressure drop, must be established by collaboration between the suppliers of the steam generators and the auxiliaries. The type of firing and the possible use of dust-eliminating equipment and its installation relative to the fan are important details to be stated.

The average steam generator today does not present a high flue gas temperature problem in the selection of a fan, as this temperature seldom exceeds 500 F. Should it be higher the fan selection can be influenced. All fan wheels do not have the same blade span, blade construction or tip speed, which factors, plus materials used, affect fan selection. A relatively high volume at a low pressure drop invariably suggests a wide fan wheel. However, the high temperature steps up the tip speed which offsets the low tip speed prompted by the low pressure drop. Thus one must consider wheel tip speed, blade and fan design, common steel or alloys required, whenever high temperature is involved.

The extraction of all possible heat from the flue gas, lowering the gas temperature at the fan, cannot be ignored as an influence. Operating near or at the dew point can result in dust adhesion to the wheel. This influences performance and may create an out-of-balance of the running gear, not only damaging the fan equipment but its driving auxiliaries. Thus, tip speeds (not to be confused with revolutions per minute) must be considered in the fan selection.

In connection with these varying temperatures, one too often neglects to obtain true performance pictures in the case of constant-speed units and there have been cases where performances were not clearly presented or understood relative to variable speed units. These discrepancies are prompted by the work involved to determine the true performance at the lower steam loads where lower temperatures prevail. It is so easy to plot a performance curve based only on the top temperature, whereas the picture based on an understanding of the actual varying temperature conditions is a composite curve resulting in higher horsepower consumption at lower steam loads. This fact is important where many hours of operation are in the lower steam loading range and true evaluation of power consumption is a factor. This phase of fan selection will be referred to again later.

With reference to varying system pressure as an influence in the fan selection, it should be definitely appreciated that the various pressure drop points should be accurately determined and, in turn, prompt careful selection of the fan as to the point of operation on the characteristic curve. While the type of driving medium cannot be ignored, it will not for the moment be considered lest it confuse the immediate problem. Due to system auxiliaries, such as superheater and dampers, the pressure does not follow so-called fan laws. The varying system pressure must be carefully noted in order to determine if it will be advisable to select a fan for top duty at its peak of static efficiency and/or static pressure characteristic. In making this study, accuracy of pressure drops, steam loading range and general experience must be taken into consideration. Several fans of one type or different types could be selected to meet the top or test block duty. However, each would have a different performance if specified duty did not prevail in the field and have a different composite pressure and horsepower performance curve for the various lower pressure drop points specified.

Controlling Factors

The test-block pressure drop specified is the first controlling factor. If, based on experience, this is specified conservatively, but such does not prevail in the field, the lower pressure drops will be different and present a composite system curve, influencing overall fan performance. By this same line of reasoning the reverse will obtain and for this reason each individual's experience is entitled to expression in the selection of the fan.

Type of firing has bearing on induced-draft fan selection for there is a vast difference in character of the flue gas with different firing methods not only with coal but with gas- and oil-fired units, which must be analyzed from a different angle. There are several phases to be considered, the most important of which, in the case of coal-fired

* From a paper before the Midwest Power Conference, Chicago, April 7, 1948.

units, is the ash content of the flue gas; whether or not fly-ash precipitators will be employed, and if so, whether they are to be placed before or after the fan. If collectors are not used, will space be allocated for possible future installation. Even the fly-ash collector performance should be a factor for consideration in long planning. System pressures are considerably higher today than twenty years ago, thus requiring fan tip speeds more than twice those of their predecessors, and this in itself is a factor in design, especially where fly ash is involved.

Fly-ash deposit and erosion are subjects of great concern and interest. The deposit is constantly affecting the system, more severely of course in pulverized-coal-fired units than in the grate or spreader-stoker-fired units. Thus the fan has to be considered in the light of work to be done under varying system conditions. Again, the point of operation on the fan characteristic curve, reliability of specified duty, as well as fly-ash influence on the system must all be combined in the consideration of the fan selection.

Erosion presents two distinct problems, namely, maintenance of fans and boiler outage. Because of operating temperatures there are no known materials capable of withstanding fly-ash erosion for a length of time considered economical by the owner. To determine fairly accurately what different materials will endure in one fan is possible by investigation, but it is the author's opinion that it is not possible to make a similar check that will apply to various types of fans.

There is no sure method to compare types of fans. Two steam generators built from one print, each eqipped with different types of induced-draft fans, do not deliver to the fan the same character or quantity of fly ash. To compare different types or sizes of steam generators and their respective induced-draft fans is folly, for fan type changes have been made on steam generators with confusing results. One type of fan remained in operation three months and averaged this operating period for over one year. It was then replaced by a different type, which ran nine months average time. The same substitution was made on another installation with exactly the reverse results as to which type gave the longer life. The immediate question arose as to the firing, steam loading and coal conditions being the same for the two comparative periods. A difference in any of the listed conditions could and unquestionably did contribute to the unconvincing comparison.

Protection Against Wear

For any given type of fan, many different schemes are employed to reinforce or protect parts subject to excessive wear. Naturally these involve expense, which costs must be weighed against time and maintenance, as well as any possible influence on performance affecting power consumption. The general overall design of fan is influenced by erosion. Accessibility to worn parts and simplicity of repairs or replacements are factors requiring intelligent practical study by the supplier in the interest of the owner.

To eliminate or minimize erosion, there is only one relief, the installation of dust precipitators ahead of the fan. Collectors are not inexpensive in first cost and impose increased operating costs due to additional pressure drop. However, they have been known to eliminate boiler outage over a long period of time which outage was previously an expensive loss due to fan erosion. It is advisable to state at this point that due consideration must be given fan erosion in the fan selection and design, even though dust eliminators are used. All collectors do not perform alike.

Steam Loading

The next important influence upon the selection of an induced-draft fan is the steam loading of the generator. It is impossible for the owner or his agent to make a definite breakdown of the annual or eight thousand hours of anticipated operation. But this should be stated as accurately as possible and given in the specification. As mentioned previously, more than one fan of a type and different types of fans can be justifiably considered for a given duty or range of operation. There may be only a few hundred hours' operation in the top 25 per cent of steaming capacity, with 50 per cent of total time at half steaming capacity; or, as in the case of a standby steam unit, the load distribution may be 10 per cent capacity for 90 per cent of the total time.

It is necessary to mention at this point that the type of volume control is a definite factor in consideration of the steam load and its influence upon fan selection. If louvre or vane control is to be employed for a standby unit, it is possible to select a fan to the right of its static efficiency and consume less power at 10 per cent steaming capacity than a fan picked for the peak of the static efficiency.

For this reason the steam loading distribution is an important factor; first, in order to determine the type of volume control, and second, because the size of any given type of fan for the horsepower characteristic is unique to the fan design.

If the reverse of a standby plant is under consideration, the fan should be selected at or near the peak of its static efficiency. Steam generators, having a varying load, daily or otherwise, operating between 50 and 85 per cent, will influence not only the fan selection but also the type of volume control. The induced-draft fan for such a boiler and particularly a coal-fired unit, should be arranged for variable speed, not only to conserve power but to minimize erosion.

Number of Fans for Large Boilers

Growth in the size of boilers has created a problem. Shall the induced-draft duty be imposed on one large or two smaller units. If two fans are employed, a clear understanding should be obtained as to the performance with only one fan operating. Considering all types of fans, the potential performance of one fan so operating, ranges from approximately 60 to 80 per cent boiler capacity, according to the fan design and the location of the operating point on the characteristic curve for the original half of top two-fan duty. The horsepower required to satisfy this optimum condition can be 80 per cent above the two-fan operation of one fan. Accordingly, only a percentage of the potential is usually provided for in the driving medium with precautionary measures in the volume control to prevent excessive overload on the driver.

The application of two fans to a single boiler brings out an old controversial issue namely, the type of fan most

suited for such duty. However, all types have been used successfully and there seems to be less fear today as to the type selected, with more interest being shown in the potential performance of one fan operating on a two-fan system. The two-fan installation with separate driving equipment and control, does not originate entirely from fan size. Other system conditions or auxiliaries influence this scheme, so it is advisable to study system design prior to any hit-or-miss method of selecting the fan.

In the case of constant fluctuations or sudden changes in boiler loads, the duty imposed on the induced-draft fan is more critical than with constant load when considered from the control angle. If the volume control is by variable speed, the weight of rotating parts, both fan and driving mechanism, as well as sensitivity of the control, must be given due consideration.

Constant-speed units with vane or louvre control should not be encouraged if the steam load is definitely variable in the mid-capacity range. Too often the margin between the dirty and clean system pressure drop does not prevail and the test-block duty pressure specified is actually excessive, resulting in operation of the control at a point equivalent to a quarter of the anticipated test block duty. Variable speed would serve more economically and create less wear and tear on the entire fan, and particularly if the boiler be coal-fired, with low or no ash elimination.

Forced-Draft Fans

The forced-draft fan is becoming a more difficult problem today, but even so, not to the extent of the induced-draft fan, for it handles fairly clean air at ambient temperatures. However, considering each possible factor that today influences selection of the forced-draft fan, may it be stated that early history requirements favored but one type, the simple backwardly inclined bladed fan. For a given duty, this design operates at a higher rotating speed than other types and with free inlet openings. Before introduction of inlet vanes it presented no bearing span problem at selected speeds. The higher rotating speed made possible more economical drivers regardless of type and the basic nonoverloading horsepower curve assisted cost-wise in selecting the driver, provided the fan was advantageously selected as to the point of operation on its characteristic curve.

With precedent well established and conditions changed, it is becoming more difficult to select a fan. In order to give temperature relief to sections of the building housing the steam generator, and at the same time to take advantage of this higher temperature air for combustion, the fan inlet must be enclosed except for an alternate arrangement. The addition of an inlet box or boxes on a double-inlet unit materially increases the bearing span and the higher air temperature increases the tip speed. These factors have considerable influence on design and construction and thus make the selection more difficult. The bearing span could create a shaft condition at the wheel inlet eye beyond allowable proportions and consequently influence performance. This possibility dictates a narrower fan of larger diameter at lower rotating speed, which of course, could affect the driving medium.

This enclosed fan to handle warm air is further prompted by air preheater conditions. In order to obtain maximum heat transfer with minimum trouble due to operating at or near the dew point, warm air is shunted from the air heater outlet back to the fan inlet. Unfortunately, this return air is not clean and the dust is highly adhesive, so judgment must be exercised in selecting and designing a high tip speed unit to operate under such conditions.

System pressures on the forced-draft side of the furnace are much higher than when the backwardly inclined bladed fan became a generally accepted type. These high pressures require high tip speeds at relatively high air velocities, all of which contribute to noise. Thus this phase of the problem must be considered in forced-draft fan selection and especially so in the case of pulverized-coal, or gas-and oil-fired furnaces. Only in the case of a stoker-fired unit would the nonoverloading type of fan be a wise and precautionary consideration, and provided it were selected to operate at a definite point on its characteristic curve; otherwise, it could overload the driver as could any other centrifugal fan.

Single-Shaft Combination

In an attempt to economize relative to capital cost or space, the single-shaft forced- and induced-draft fan combination was conceived some years ago. This followed the coupling of two separate fans in order to require but one driver. The single-shaft setup makes very difficult the selection of either one or the other of the two fans. Most fan units are driven by alternating current motors where fixed available speeds establish the first influence. Naturally, the larger power-consuming unit would be determined first and selected to operate at its most efficient point. But unfortunately, as mentioned above, the two system curves do not follow the same pattern, so the first consideration to such a combination must be the type of volume control. The constant-speed unit with mechanical volume control devices on each fan is not as difficult a problem as the preferred variable-speed unit. Even so, a sacrifice in efficiency usually develops in the selection of one of the two fans in the combination.

If variable speed is selected the forced-draft fan should receive first consideration on account of its system curve. At reduced steam loads, two separated fans would not change speed in unison, the rate being greater in the case of the induced-draft fan. To take care of this difference in the single-shaft setup, the required volume modifications of the forced-draft fan are accomplished by speed changes. This partially corrects the induced-draft fan and further volume adjustment of the induced-draft fan can be had by means of orifice control.

Such a scheme has its limitations and hazards. Therefore, if economic or field conditions suggest a single-shaft unit, careful study should be given to both fan duties, particularly for accuracy. Errors either above or below actual requirements cannot be easily corrected nor is it economical to operate either fan on an artificial system. Two separated units are more flexible from the standpoints of design, selection, operation, change or correction.

Type of Drive

The method of drive exerts a definite influence upon the design and selection of both fans. For large units,

direct drive is preferred, and alternating-current motors do not have the top speed choice possible in direct-current motors. It is in the case of the dual motor-driven unit that complications can arise both in the fan selection and field operation. Fan design must withstand not only the starting shock but the switch-over from one motor to another. If the boiler loading fluctuates in the vicinity of this change in speed, the running gear must be capable of frequent speed changes and be sufficiently sensitive to prevent overriding. With turbine-driven units, there is no limited number of usable top operating speeds, but the fan design should provide for the possibility of exceeding by 15 per cent the fan test block duty speed. In the selection of a fan for turbine drive it is prudent to consider a motor speed for maximum fan duty. However, steam demand may exceed the supply, in which case motor substitution may prove expedient.

In connection with small boilers, efficient fan operation should be a factor. However, inherent design for durability of the small induced-draft fan suggests first consideration. Heat absorbing auxiliaries in the system and efficient dust eliminators are not always economical or physically possible. This size fan does not require direct drive so important to larger units. Thus sturdy fans subject to simple operation and maintenance are wise selections.

Some Early Water-tube Boilers

By C. G. R. HUMPHREYS*

MINDFUL of what has been done, we strive at the same time after the things yet to be done." This free translation of words emblazoned on the emblem of the Newcomen Society, is a not irrelevant maxim to introduce here.

The first onslaught of the Industrial Revolution in England received its impetus largely because such pioneers as Savery and Newcomen harnessed the power of steam to drive their crude beam pumping engines. These engines moved to the amazement of the onlookers, but the boilers from whence came the motivating fluid did not impress them, and no smooth tongued Samuel Smiles recorded their story for the enjoyment of future engineers.

One of the first men to approach the science of thermodynamics was the Marquis of Worcester. In 1663 he published his euphuistic "Century of Invention" wherein he expounded vaguely the great power exerted by steam when its expansion is limited (1). Elsewhere he wrote of his work at Raglan Castle, where to this day may be found foundation marks and other evidences of some steam engine or engines. It was he who devised "the first globular boiler and water cask used as a 'steam water-lift' " (2).

In 1698, Savery patented and erected a metal construction similar to that of Worcester, but devised with more scientific forethought. In 1730, we have record of Dr. John Allen's assertion that half the heat of a fire was lost in boilers because of the short time the furnace gases were in contact with the boiler heating surface. To extend this time, he designed a boiler with a serpentine smoke flue surrounded by water.

The first known water-tube boiler, if we disregard such as a small cast bronze room-heating unit found among the ruins at Pompeii, was constructed in England in 1766. Its inventor was William Blakey about whom we know little. We can place his birth date in 1711 and his last recorded works in 1792. We know that he was a versatile man, and a sometime maker of clocks and watchworks; a steam engineer; a medical practitioner who professed knowledge of treatments for hernia, and history also suggests him to have been a charlatan. His boilers, Fig. 1, were attempts to improve the Savery method of raising water, and we read into this and other similar illustrations (3, 4) the water-tube boilers somewhat akin to sectional-header units. Referring to Fig. 1, the furnace *a* contained copper tubes *b*, *c*, and *d*, completely filled with water, and these were connected by small copper pipes. A funnel *f* is shown for supplying the boiler with water, but a force, or feed, pump soon made this inexpedient. At *e* is a blowdown cock, for it proved essential that boilers be kept clean by blowing and draining water through the whole unit.

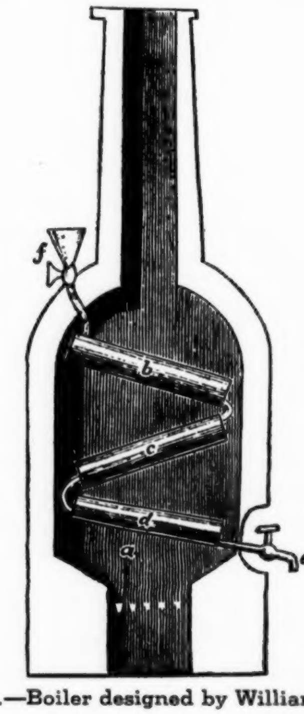

Fig. 1.—Boiler designed by William Blakey

Between 1772 and 1776 Blakey, whose writings are sometimes ascribed to "Mr. B," made many improve-

* Research Dept., Combustion Engineering Company.

ments to his boilers, but the same general picture will suffice. The lowest tube, or tubes, contained water and those above effected some superheating, but there are no references to any parts which can be likened to boiler drums or steam receivers. Nor are there any records of steam conditions, or boiler capacity.

Blakey's efforts in England, France and Holland were first acclaimed by scientists of his day, but ultimately his works received declamations, and he appears to have forsaken this field for a medical career.

Hornblower[1]—one of several brothers who achieved success as builders of beam engines—records public opinion as follows (3):

"An accident terminated the event as to the experimental engine, (Savery engine) by one of the steam

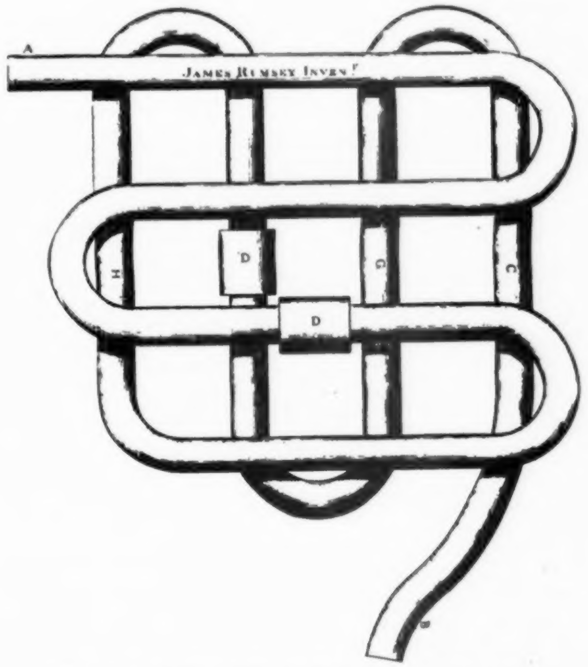

Fig. 2.—Elements of the Rumsey boiler

vessels bursting through the force of steam, though much under the degree of power proposed by the Cornish gentlemen. Such is the degeneracy of man, that whilst the States General of Holland were pluming Blakey with the gaudiest expressions of approbation, not one instance is to be found in which he met with that support he had been led to anticipate."

Contemporarily with Blakey in Europe were the water-tube boilers of the forward looking James Rumsey (1743–1792) in America, knowledge of whom is somewhat incomplete. He built steamboats which plied successfully as long ago as 1786. His boats operated on the reaction jet principle and we find his claims to originality hotly disputed by John Fitch. In any case, it appears reasonably certain that his water-tube boilers, Fig. 2, appeared in 1785 and were the first of this type constructed in this country. In a rather rare *Specification*, published in Philadelphia in 1788, he described his boiler as a long continuous coil of iron pipe set over a fire, and it resembled a bottle case. The example he gave consisted of 2-in. diameter pipes connected together by screwed couplings to form a total length of 200 ft of continuous pipe which "may be set in a furnace four feet square inside, and two and a half feet high, and perhaps may make a sufficient quantity of steam, for the largest engines now extant, as the surface of this pipe will be upwards of one hundred and fifty square feet, which will be exposed to the fire at every point as it will lie among the burning fuel."

It is clear that this boiler, as illustrated and described, had a serious deficiency, for it was purely a flash boiler. Rumsey expressed his awareness of this drawback in the "Columbian Magazine," May 1788 in which he wrote: "Perhaps this boiler might be improved by adding a steam vessel on its top which would receive much heat from the fire round the pipe and take no more fuel" (5, 6).

Rumsey received encouraging comments from such great men as Benjamin Franklin, Thomas Jefferson and George Washington. Indeed, Franklin formed "The Rumseian Society" and became its president. He sent Rumsey to England to secure patents on his boat and boiler and to obtain the necessary capital. There Rumsey wrote: "This may truly be called the crisis of my life. Should I succeed, I shall gain more reputation than I ever thought possible to fall to the share of any one man. If I fail, I shall be ridiculed and abused in all the public prints in Europe." However, he was neither ridiculed nor abused.

Rumsey received encouragements from James Watt, but died a year before his boiler was successfully applied. He was buried in an unmarked grave in London.

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[1] Probably Jabez Carter Hornblower.

World-Wide Oil Demand and Supply

By R. M. BARTLETT

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In the following excerpts from an address before the Fuel Oil Distributors Association of New Jersey on April 30, 1948, Mr. Bartlett reviews the sources of petroleum supply and present demands, including those under E.R.P. Imports now exceed exports, but any break in relations with eastern nations would likely result in loss of Middle East crude and necessitate drastic rationing. Until the tanker situation is improved conservation is needed. Included is a brief comparison of synthetic oil production from natural gas, coal and shale.

IN 1947 world oil consumption was 13 per cent greater than in 1946, the equivalent of a gain of about 1,000,000 bbl per day, of which slightly more than one-half was in this country. Unfortunately, supplies of petroleum products to meet the continuing increased demands throughout the globe are not so readily available, and the problem of supply in the United States is greatly influenced by the world's requirements and the supplies of crude oil, refinery capacity and transportation.

Up to the war period, petroleum supply and demand the world over were in fairly good balance. The United States produced and refined almost two-thirds of the world's requirements, whereas the Eastern Hemisphere and other parts of the world were supplied from sources closer to them. But during the war, many of these sources of supply and refineries were destroyed. However, the requirements for oil in all parts of the world have now greatly increased. Total petroleum requirements of the European Recovery Program for the fiscal year beginning July 1 will be about 987,000 bbl per day, of which nearly 10 per cent will be supplied by the United States. About 450,000 bbl will come from foreign production of American companies.

In 1947, the United States produced approximately 5,100,000 bbl of crude per day, South America 1,600,000 bbl and the Eastern Hemisphere, exclusive of Russia, 1,100,000 bbl. This makes a total for both hemispheres of 7,800,000 bbl. This year it is expected that U. S. production will be increased by at least 400,000 bbl per day, South America 200,000 bbl and the Eastern Hemisphere, again exclusive of Russia, 250,000 bbl. So the world production of crude oil will be 8,650,000 bbl. This is a net global gain of more than ten per cent. Estimates have been made that by 1950, barring unforeseen developments, world consumption might reach 10,000,000 bbl per day. Not much is known about Russian production, yet one point is crystal clear, and that is the Russians are not diverting any of their oil to the democratic countries.

It is expected that during the present year the industry in this country will be refining at the rate of about $5^1/_2$ million barrels per day and in South America and Canada another 1,600,000 bbl. In the Eastern Hemisphere, the 1948 rate is expected to reach approximately 1,300,000 bbl, making the world total 8,400,000 bbl per day. Taken as a whole, these figures indicate that current consumption and output are almost equal, with no opportunity for surpluses to accumulate. It must be kept in mind, however, that the United States is now firmly established as a net importer. According to a recent Bureau of Mines forecast, it is estimated that our average imports of crude and petroleum products will exceed our exports by approximately 102,000 bbl per day over the twelve-month period commencing April 1, 1948.

Today, the available crude in the Eastern Hemisphere is between 50,000 and 100,000 bbl per day in excess of the refining capacity. Therefore, in order to supply additional products urgently needed in the European Recovery Program, a number of our domestic companies are importing crude and refining it in this country. It is then re-shipped overseas as refined products—often to nations near the source of the crude. In addition, Caribbean countries are also shipping about 500,000 bbl per day of crude and products to the Eastern Hemisphere.

This is uneconomical, of course, and it is important that refineries be set up at points in Europe or elsewhere to operate on crude from the Eastern Hemisphere. Therefore, it is impossible to consider world demand without placing E.R.P. in a very prominent position, and the more we encourage the aided countries to construct and produce, the less will it be necessary to continue to extend financial assistance.

According to the U. S. Bureau of Mines, the expectation is that our 1948 exports of petroleum products will be about 20 per cent less than last year, and each succeeding year we should be called upon to export less gasoline and fuel oil.

Even so, we shall still have problems here in this country. Over the years, our geologists and wildcatters have been able to constantly increase the proved reserves. Last year, despite record production, our proved reserves were increased by almost three per cent. Experi-

ence indicates that as time continues, the discovery of additional reserves in the United States becomes more difficult. According to recent testimony before the House Committee on Armed Services, world-wide proved reserves are estimated at more than 76 billion barrels, of which there are about 24 billion in the United States.

Middle East Has Largest Reserves

The largest proved crude oil reserves, according to present knowledge, are in the Middle East, where there is an estimated 20 per cent more than the entire proved reserves in the United States. This year it appears that an average of at least 30,000 bbl a day of crude will be brought into this country from the Middle East. In addition, the Navy is picking up substantial supplies from that area, thus relieving the pressure on domestic oil. It is expected that by 1949 this country will be receiving at least double the 1948 quantity, increasing to approximately 150,000 bbl a day by 1951–1952, and possibly half a million barrels by 1955. It is believed that approximately 600,000 bbl per day will be imported from South America by 1951–1952, thus making our total imports by that time about 750,000 bbl, and approximately a million barrels daily by 1955, from the Middle East and South America combined.

At present Middle East pipe lines are carrying about 100,000 bbl of oil per day from Iraq to the Mediterranean. As is well known, several lines are under construction from the Persian Gulf area to the Mediterranean, and eventually it is expected that a million barrels of crude per day will be handled in this manner. Such lines save 2500 to 3000 miles of water transportation. Pending completion of these pipe lines and even for a short period thereafter, certain studies indicate that there will not be sufficient tankers to take care of world demand.

More Tankers Needed

A tanker with a capacity of 100,000 bbl now requires about 57 days for the round trip between New York and the Persian Gulf. This means it could deliver crude in New York at the average rate of approximately 1680 barrels per day. One hundred tankers would therefore bring in an average of 168,000 bbl per day of mid-East crude. This is only $1^3/_4$ per cent of the world demand this year. It is therefore very evident that a greatly increased tanker fleet will be needed.

While boats are about in balance to meet today's minimum requirements, the margin is too close for comfort, and several companies have included in their budgets provision for the purchase of various numbers of big tankers. However, it will be several years before these tankers can be delivered, and conservation steps must be an essential part of our economy in order to avoid spot shortages during the next year or two.

Another important phase, which must be considered in connection with the importation of crude is, that for each ton of steel used, from five to ten times as much oil can be produced in countries outside the United States, as can be produced domestically with the same amount of steel. The reason for this is the comparatively shallow oil fields from which the Middle East oil comes, and the tremendous volume of oil per well. In making this statement, full regard is given to the steel required for transportation of the crude to the refineries of this country and to other areas where the finished products are needed. In this connection, the average daily production of crude in the United States is about 12 bbl per well; in Venezuela, about 250 bbl; and in the Middle East, about 4000 bbl.

It is therefore quite obvious how important it is for the United States to have a foreign policy that will support the operations of American oil companies in the Eastern hemisphere. Any break in our relationship with those countries, resulting in the loss of Middle East crude, would have a calamitous effect on our domestic supply program. This might immediately necessitate rationing, far deeper than ever before, if we attempted to still supply the countries to which we are committed under the E.R.P.

Synthetic Oil Research

No consideration of the world petroleum supply picture would be complete without a look at the progress which has been made in synthetic fuel research and what may be expected from it. We are using our crude oil reserves at a high rate. But, there is another reason for synthetic fuel research which may be more urgent than the conservation of our crude reserves. That reason is the possibility that our foreign sources of crude may be cut off by war. We would only be deceiving ourselves if we close our eyes to these possibilities, and the oil industry and the Government have been cooperating during the past few years on the problem of making our country self-sufficient.

There are three chief methods of producing synthetic fuel or gasoline: The first is from natural gas; the second from coal; and the third from oil shale. Their relative merits are as follows:

Production of synthetic fuel from natural gas is subject to certain disadvantages:

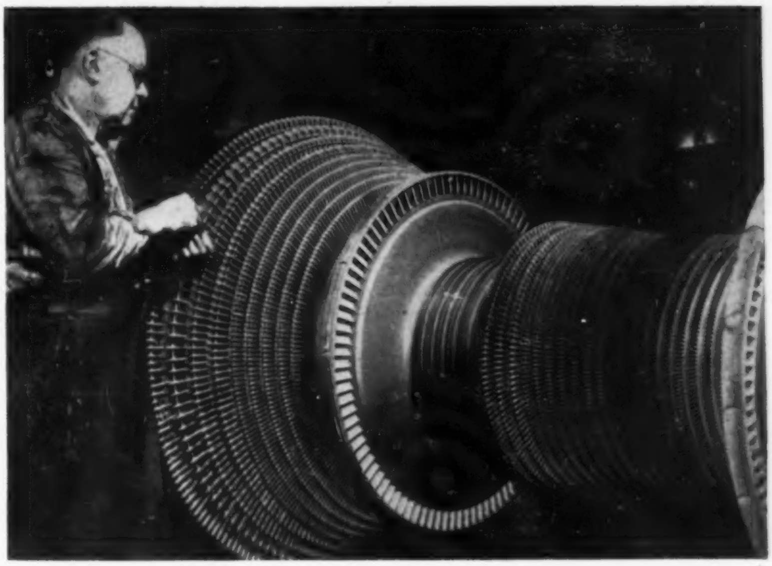
1. It uses up about 50 per cent of the Btu value of the gas to convert the remaining 50 per cent into gasoline
2. The plants are costly
3. They require large quantities of steel
4. They consume a large quantity of water for cooling, etc., which is not always easy to obtain.

Conversion from coal has the following disadvantages:

1. It consumes about 60 per cent of the Btu value of the coal to convert the remaining 40 per cent into gasoline
2. The plants are costly
3. They require large quantities of steel
4. There is no indication that the plants would be economic at the present time.

One of the most intriguing directions for synthetic fuel development to take is the extraction of oil from shale. This shale is not suitable for any other purpose and therefore any fuel recovered from it is a net addition to our national fuel resources, and not a waste. The process apparently requires only a moderate amount of steel and water. However, crude shale oil is poor in quality compared with petroleum, and it is expensive to refine. Nevertheless, research along this line would seem to be warranted.

Industrial Turbine Maintenance



By G. W. ANDERSON
Westinghouse Electric Corp.

Some practical suggestions for setting up a maintenance schedule as an insurance against forced outages and an outline of things that should be checked.

IT IS not ordinarily possible to develop a maintenance organization in an industrial power plant comparable with that in most of the large central station power plants. Frequently the maintenance work is performed by mechanics employed in the maintenance of equipment throughout the entire industrial property. A group of specialized mechanics for maintenance work on the power plant equipment exclusively is not usually carried on the plant payroll. For this reason the engineer in charge of the power plant must develop certain key men who can direct the work of the general mechanics during a maintenance job. The general mechanic is usually a willing worker but he does not know the importance of many of the details in maintaining a turbine. Unless his work is supervised by someone who is familiar with the equipment, an incorrectly done maintenance job may result; not because it is poorly done, but because the man doing it did not understand what was required. As industrial power plants develop in size and functions, a well trained maintenance supervisor becomes increasingly important.

A maintenance program is necessary, involving a systematic schedule of outages of the power plant equipment for inspection and repair. Frequently this is difficult in an industrial plant because such outages must be scheduled to conform with the industry's production schedule. Nevertheless, the power plant equipment must have its turn for inspection and, if necessary, repair. If this is not provided, unscheduled outages are certain to result. Usually these enforced outages come at a time when they seriously impair the industry's production. Therefore, it is not only up to the engineer in charge of the power plant to see that such a schedule is set up, but it is also up to the managment to cooperate in arranging such a schedule.

In setting up a maintenance schedule the engineer must keep a record of the condition of the equipment and make frequent reference to the operating log.

It is not possible to arbitrarily set up a definite length of operating time between general inspections of all turbines. In some cases one year is satisfactory. In other cases they may have to come more often, or a period of two years or more may elapse. The scheduling of a general inspection depends on operating performance and condition of the equipment as found during the previous inspection.

In the case of a new turbine it is generally recommended that it be opened for complete inspection at the end of the first year. This inspection may reveal developments such as deposit of foreign matter in the blading due to carryover, erosion of blading due to moisture in the steam in the lower stages, accumulations of dirt or rust in the oiling system, or indication of mechanical distress of any of the internal parts. From this inspection the engineer can decide how long a period of operation is safe before the next inspection should be made, and schedule that inspection accordingly. If the conditions found are satisfactory, perhaps a longer operating period can be made before the next inspection. However, it must be borne in mind that inspections are made for the purpose of assurance that the equipment is in good condition, and not of making repairs long overdue.

What the Log Tells

By systematically checking the operating log the engineer can obtain considerable information for guidance in setting up a maintenance schedule. Changes in pressures and temperatures almost always reveal a maintenance condition. Following are a few typical cases:

Stage pressures recorded at intervals under the same load conditions will indicate the cleanliness of the blading. If these pressures become greater under the same load conditions it is probable that carryover is depositing on the blading and is restricting the flow of steam. This indicates that an outage must be scheduled to clean or wash out the deposit before the capacity is seriously reduced or a mechanical failure results. Improvement in boiler feedwater treatment has greatly reduced the danger of trouble due to deposits of carryover in the turbine blading. It is now seldom necessary to clean out large quantities of baked mud as was frequently the case during the early days. However, even with the modern methods of treating boiler feedwater, and the use of high pressure and superheated steam, there are elements carried over with the steam that will create a deposit in certain sections of turbine blading. This conditon must still be watched.

A general increase in lubricating oil temperature bears investigation. This is due to the oil cooler becoming dirty. A schedule for periodic cleaning of the oil cooler should be set up whereby it is kept reasonably clean at all times. The formation of scale on the water side of the oil cooler tubes usually accelerates due to the increase in oil temperature it causes. Sometimes cleaning is delayed too long and the oil temperature becomes dangerously high before action is taken. The excessive oil temperature contributes to higher maintenance cost as well as damage to the oil.

Many turbines are designed for automatic extraction and/or non-condensing operation in order to supply steam at various pressures for process purposes. These turbines are equipped with regulators and control devices which must be properly maintained. By reference to the log and recording charts the engineer can determine just how well such pieces of apparatus are performing. Sticky valves or relays will become evident by the appearance of irregular recordings on pressure or flow charts. Worn linkage or failing pressure regulator diaphragms will show up as irregular speed or pressure control. If action is taken when these irregularities first begin to appear on the charts they can be eliminated by scheduling a regular inspection and cleaning of

the control equipment. If this is not done an enforced outage may result. Replacement of pressure diaphragms which are a part of automatic control equipment should be given special attention. Do not wait until the diaphragm breaks and causes an outage before replacing it. Set up a schedule to renew all diaphragms at regular intervals. They are not expensive, but their failure due to lack of proper maintenance has caused many expensive outages.

It is well to set up a regular schedule for testing the auxiliary oil pump and recording the result; also a regular schedule to inspect the control valve and replace the diaphragm in the automatic regulator which brings this pump into service. This pump stands idle a large part of the time, and is much more subject to lack of attention than a piece of equipment which is continually in operation. Turbines have been seriously damaged because the auxiliary oil pump was in poor condition and failed to start when the turbine was being shut down.

A regular schedule for checking the condition of the oil in the turbine lubricating system is also important. Most oil suppliers will gladly analyze a sample of their oil. Oil does not wear out, but it does become unusable due to contamination with water and dirt. Examine the strainer in the oiling system regularly. It will give an indication of any foreign material getting in the oil. The appearance of flaked babbit or bronze cuttings in the strainer frequently enables the engineer to discover bearing wear before actual failure occurs. This is a warning that demands action in checking operating conditions and perhaps scheduling an outage for complete investigation. Draw off a sample of oil from the bottom of the oil reservoir regularly. If water is found in the oil, steps should immediately be taken to locate the source of the water and eliminate it. Most turbine oils do not stand up very long when contaminated with water. A small amount of water in the oil will cause rust formation on the iron parts of the oiling system. Gritty particles of rust from this source will be carried by the oil to the bearings and journals, causing serious damage. In many cases the quantity of water in the oiling system will not be sufficient to appear definitely in a sample of oil taken from the bottom of the oil reservoir. Therefore, although the sample does not show water, a second step in the investigation is necessary. Examine the underside of the cover of the oil reservoir, or the upper inside of a return oil line which runs only partly filled with oil. If a gritty formation of rust is found at these locations, there is or has been water in the oil which vaporized and then condensed on these relatively cool iron surfaces. Many of the turbine oils now in use contain inhibitors for the purpose of preventing oxidation and corrosion. If a case of rusting of the interior of the oiling system develops, it is well to confer with the supplier of the oil and obtain his assistance in eliminating the condition.

The development of excessive vibration is an indication of mechanical unbalance or misalignment, which demands immediate attention. However, in many cases this vibration may have been increasing over a long period, and earlier steps to eliminate it might have prevented an unscheduled outage. It is a good plan to measure and record the amplitude of vibration at regular intervals so that a small gradual increase in vibration can be noted and correction made during a regularly scheduled outage. Small weight or reed type vibrometers are available on the market for this purpose.

The work of making a general inspection requiring complete dismantling of the turbine, should be supervised by a representative of the manufacturer. With his experience he can pass judgment on the condition of blading, nozzles, valve gear and other parts which may be showing signs of wear. These may require immediate repair or it may be that replacement parts should be ordered for installation during the next regularly scheduled outage. Here again the thought must be to predict required repairs so that they can be made before the condition of the equipment becomes so bad that a breakdown disrupts the industrial production.

In going back over the record of enforcing outages, it is almost always evident that the outage could have been prevented had certain maintenance or operating details been watched more closely. In many cases these were simple matters as outlined in the foregoing. The control of this is in the hands of the man supervising the maintenance and operation of equipment. By setting up a systematic record and schedule for making inspection, normal cleaning and minor repairs, he can eliminate a great many enforced outages, and in many cases, prevent costly major repairs.

Stabilization of Austenitic Stainless Steel

Austenitic stainless steels, of the type usually referred to as 18–8 (18 per cent chromium–8 per cent nickel), are sometimes susceptible to intergranular embrittlement or corrosion. This type of corrosion is particularly pronounced in some 18–8 steels which have been subjected to moderately elevated temperatures, in the range 700 to 1400 F, and are either simultaneously or subsequently subjected to corrosive conditions. Experience has shown that the susceptibility to embrittlement may be decreased or eliminated, that is, the steels may be stabilized against intergranular embrittlement, by the addition of titanium or columbium, usually in conjunction with a stabilizing heat treatment. A diversity of opinion has existed, however, as to the relative amounts of titanium or columbium necessary for effective stabilization of these steels, the injurious effect of carbon content, and the necessity for stabilizing heat treatments. Accordingly the National Bureau of Standards was requested by the Navy Department to undertake a study of factors affecting the stabilization of the 18–8 type of steels.

Using both experimental and commercial steels made to a base analysis of 18 per cent chromium and 10 per cent nickel, the effect of variations in carbon content, in the ratios of columbium to carbon and of titanium to carbon, and of different heat treatments, was studied by Samuel J. Rosenberg and John H. Darr of the Bureau's thermal metallurgy laboratory. The test ordinarily used to induce susceptibility to intergranular attack consists of heating the steel for two hours at 1200–1250 F (this is termed the sensitizing treatment), followed by exposure for two days to a boiling solution consisting of 100 ml H_2SO_4 (sp. gr. 1.84), 100 g $CuSO_4.5H_2O$, and 900 ml distilled water. The specimens are then dropped on a steel plate to note whether they have lost their metallic ring, and are bent 180 deg over a rod whose diameter is equal to the thickness. The outer fibers are then examined for cracks. Steels which are immune to intergranular embrittlement have an unimpaired metallic ring and show no cracks after bending. Extremely susceptible steels lose their metallic ring completely and crumble on bending. In addition to these tests, all specimens studied at the Bureau were subjected to metallographic examination as well as a measurement of electrical resistivity, since intergranular corrosion increases this property considerably.

As part of the investigation a variety of test conditions, some of them quite severe, were used to study susceptibility to intergranular attack. Specimens were sensitized at temperatures ranging from 840 to 1380 F for periods up to 21 days, followed by exposure to the boiling acidified copper sulfate solution for 14 days. It was found that the most severe sensitizing treatment was 8 or 21 days at 1020 F. Compared with this, the commonly specified treatment of two hours at 1200 F is relatively mild.

Considering the steels which contained no stabilizing elements, the tests showed that all were vulnerable to intergranular attack. Decrease in carbon content, however, decreased the degree of vulnerability.

In the columbium- and titanium-bearing steels, carbon content within the range of 0.06 to 0.13 per cent had no influence upon the resistance to intergranular attack except as it influenced the Cb/C or Ti/C ratios. Steels varying in carbon content but having similar ratios of Cb/C or of Ti/C had approximately the same degree of susceptibility to intergranular attack regardless of the total carbon content. The steels showed greater resistance to attack when annealed at 1800 F than when annealed at 1975 F.

Stabilizing heat treatments at 1600 F had a negligible effect upon the resistance to intergranular embrittlement of the columbium-treated steels so that these steels carrying a sufficiently high ratio of Cb/C may be used without giving them a stabilizing heat treatment. However, the performance of the titanium-treated steels carrying the higher ratios of Ti/C was markedly improved by such treatments. When properly treated, substantially complete immunity to intergranular attack may be obtained with a minimum ratio of Cb/C = 10 and Ti/C = 5. For more "fool-proof" immunity, these ratios should be 12 and 8, respectively.

A.S.M.E. SEMI-ANNUAL MEETING

AN EXTENSIVE program of technical sessions, an engineering exposition and numerous inspection trips, luncheons and dinners will occupy the entire week of May 31 through June 5 for the Semi-Annual Meeting of the American Society of Mechanical Engineers in Milwaukee. Headquarters will be at the Hotel Schroeder.

There will be around eighty scheduled papers and talks, including sessions on turbine deposits, steam turbine design, fuels, development of pulverized coal firing, and gas turbines. These will be of special interest to power engineers and are listed as follows:

Tuesday, June 1, 9:30 a.m.

Introductory remarks by **J. T. Rettaliata,** director of Mechanical Engineering Dept., Illinois Institute of Technology, Chicago, Ill.

"Gas Turbine Power Plants for Operation with Low Cost Fuel," by **John Goldsbury,** mechanical engineer, Turbine Engineering Div., General Electric Co., West Lynn, Mass.

"The Gas Turbine with a Waste-Heat Boiler," by **G. R. Fusner,** Gas Turbine Engineering Div., General Electric Co., Schenectady, N. Y.

"Design and Fabrication of Welded High-Strength Pressure Vessels," by **J. J. Chyle,** director of welding research, and **H. W. Brock,** manager, Ordnance Section, A. O. Smith Corp., Milwaukee.

Tuesday, June 1, 12:15 p.m.

Nuclear Energy General Luncheon

Dr. O. C. Simpson, associate director, chemical div., Argonne National Laboratories, Chicago. Subject: "Some Engineering Problems of Peacetime Atomic Energy Research."

Tuesday, June 1, 2:30 p.m.

"Construction of a Gas Turbine for Locomotive Power Plants," by **W. B. Tucker,** Turbo-Power Development Dept., Allis-Chalmers Manufacturing Co., Milwaukee.

"Continental and American Gas Turbine and Compressor Calculation Methods Compared," by **Dr. Frank Martinuzzi,** director of research, Coordination on Gas Turbines, Italian National Research Council, Rome, Italy.

Wednesday, June 2, 9:30 a.m.

"Turbine Blade Deposits—Burlington Generating Station," by **W. E. Karg,** superintendent Burlington Generating Station, Public Service Electric & Gas Co., Newark, N. J.

"Prevention of Turbine-Blade Deposits," by **G. C. Daniels,** chief mechanical engineer, Commonwealth and Southern Corp., Jackson, Mich.

"Reduction of Turbine and Superheater Deposits by Internal Treatment with Magnesium Chloride in Absence of Phosphate," by **W. A. Pollock,** senior test engineer, and **F. H. Long,** test engineer of power plants, Wisconsin Electric Power Co., Milwaukee.

"High-Pressure Turbine Deposit Experience," by **W. L. Webb,** mechanical engineer, American Gas and Electric Service Corp., New York.

"Low Silica Content of Boiler Water Minimizes Turbine Silica Deposits," by **J. N. Ewart,** chief mechanical engineer, and **T. J. Finnegan,** chemical engineer, Buffalo-Niagara Electric Corp., Buffalo, N. Y.

Thursday, June 3, 9:30 a.m.

"Design of Main Cylinder Joints in Steam Turbines," by **E. M. Golonka,** steam turbine dept., Allis-Chalmers Manufacturing Co., Milwaukee.

"Steam Turbine Governor Regulation," by **C. E. Kenny,** engineer, **G. E. Scott, Jr.,** and **C. L. Ringle,** designers, steam turbine dept., Allis-Chalmers Manufacturing Co., Milwaukee.

Thursday, June 3, 9:30 a.m.

Symposium: "Effects of Trends in Coal Quality and Availability on Boiler Design."

Moderator: **E. D. Benton,** director of research, Fuel Engineering Div., Ohio Coal Association, Cleveland.

Discussers: **E. M. Powell,** Combustion Engineering Co., New York; **J. E. Brunner,** The Glidden Co., Cleveland; **V. C. Leach,** Peabody Coal Co., Chicago; and **E. C. Miller,** Riley Stoker Corp., Worcester, Mass.

Friday, June 4, 9:30 a.m.

"Early Work in Pulverized Coal and High-Pressure Steam Generation at Milwaukee," by **Fred L. Dornbrook,** chief engineer of power plants, Wisconsin Electric Power Co., Milwaukee.

"Present Status of the Art and Science of Pulverized Fuel Burning," by **B. J. Cross,** manager, Research & Development Dept., and **E. M. Powell,** Calculating Div., Combustion Engineering Co., New York.

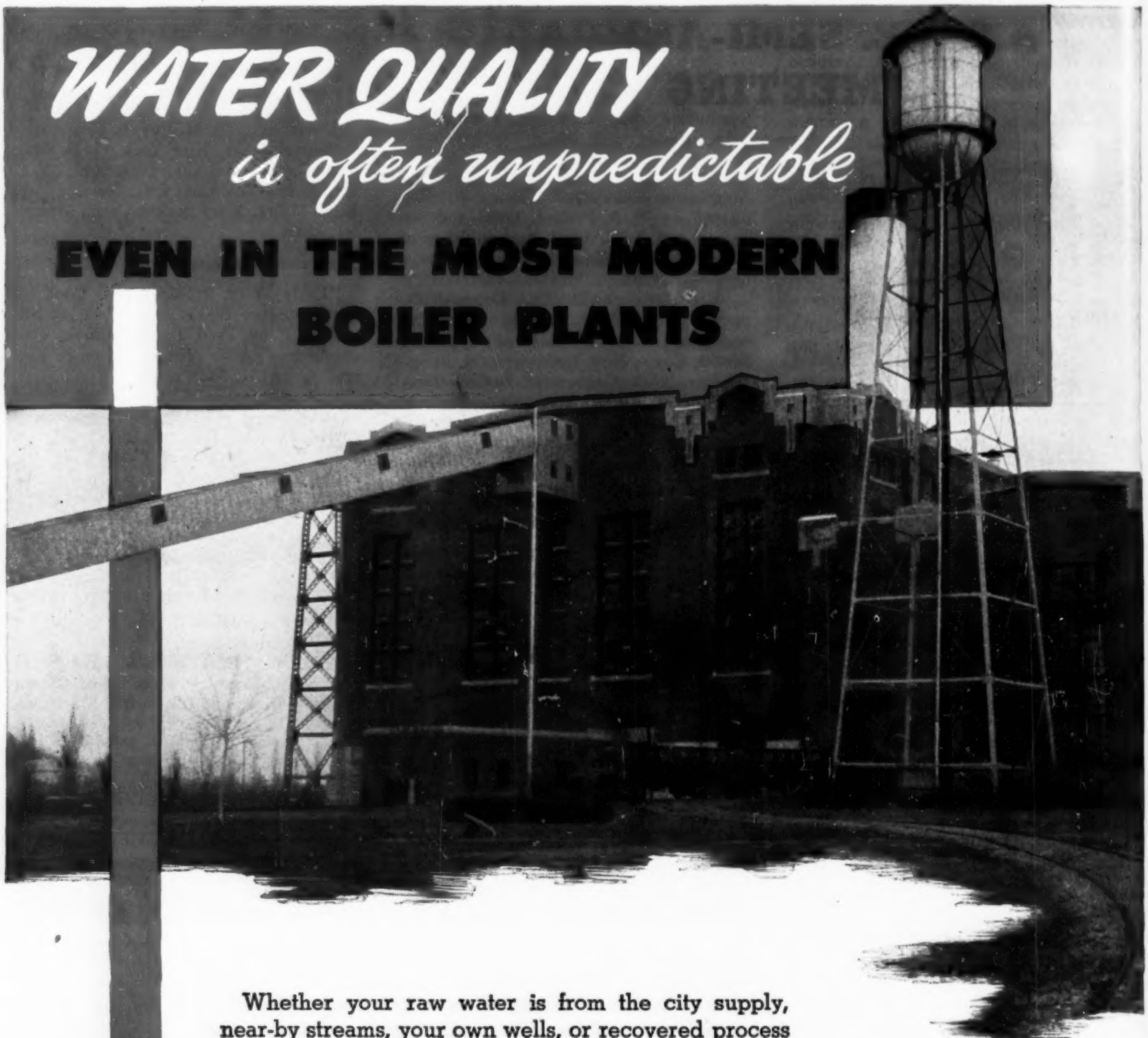
"Fuel Performance at Port Washington Station," by **W. A. Pollock,** senior test engineer of power plants, Wisconsin Electric Power Co., Milwaukee.

Friday, June 4, 7 p.m.

Dinner sponsored by the University of Wisconsin.

Speakers: **Hon. Julius A. Krug,** Secretary of the Interior; **Hon. Oscar Rennebohm,** Governor of Wisconsin; **Dr. Edwin B. Fred,** President, University of Wisconsin.

Saturday, June 5.—Inspection Trips.


WATER QUALITY
is often unpredictable
EVEN IN THE MOST MODERN
BOILER PLANTS

Electricity Supply in Berlin

Commenting on the electricity supply in Berlin, *Engineering* (London) of April 16 states that before the war Berlin was supplied mainly by two large hard-coal-fired stations—West Station of 298,000 kw, located in the present British zone, and Klingenberg Station of 270,000 kw, located in the eastern suburbs. Other sources of supply through transmission lines were the large brown-coal-fired stations at Golper-Zschornewitz, Trattendorf, Lauta and Finkenheerd, in what is now the Russian zone, and hard-coal-fired stations at Charlottenburg (109,000 kw), Spandu (56,000 kw), Unterspree (36,000 kw) and Schoneberg (13,000 kw), all located in what are now the British, French and American zones. The Rummelsburg station of 81,000 kw is in the Russian zone. Some of these plants were more or less obsolete and were employed for standby service.

In June 1945 the Russians removed all equipment from the West Station and part of Klingenberg. Hence at present about half of Berlin's demand is supplied by the equipment still in Klingenberg, about 15 per cent from the Russian zone, and the remainder from the above-mentioned uneconomical stations.

However, the Anglo-American Control Office has announced that West Station will be re-equipped and orders have been placed with the German bizonal administration for procurement of the necessary equipment.

Contract Awarded for Synthetic Fuels Plant

Secretary of the Interior J. A. Krug has announced the award of a $4,413,250 contract to Koppers Company, Inc., of Pittsburgh, Pa., for the design and construction of a gas synthesis (Fischer-Tropsch process) demonstration plant near Louisiana, Mo., to produce oil from coal.

This is the third and last of the demonstration or semi-commercial scale plants planned under the synthetic liquid fuels research and development program of the Bureau of Mines. Funds were authorized by the O'Mahoney-Case bill approved recently by Congress and signed on March 15 by the President.

Construction will begin within three months and it is anticipated that the plant will be completed within 15 months after work begins. It will have a capacity of 80 barrels of oil and gasoline daily and will include a coal gasification unit. The gas synthesis plant will be erected adjacent to the Bureau's hydrogenation (Bergius process) demonstration plant now under construction near Louisiana, Mo., on the site of the Missouri Ordnance Works, a wartime synthetic ammonia plant. The 200-barrel-a-day hydrogenation plant is expected to be completed next summer.

Although using different processes, both of these plants will employ coal as the raw material for liquids fuels. An oil-shale demonstration plant already is in operation near Rifle, Colo.

NEW CATALOGS AND BULLETINS

Chemical Feeders

A bulletin on chemical feeders has just been published by Liquid Conditioning Corp., Linden, N. J., manufacturers of equipment and materials for water-treatment and Liquid conditioning processes. This bulletin explains the purposes and applications of the different control systems for feeding chemicals to raw water to correct or eliminate impurities, and describes in detail the various types of apparatus available for the purpose. A section of special interest describes the latest development in chemical feeders, known as the "Decantrol" which embodies several advances over older types.

Drainers

Cochrane Multiport Drainers are described in Publication 4340, issued by Cochrane Corp., Philadelphia. These are designed for continuously removing large quantities of condensate from evaporators, heaters, separators, coils and steam lines. Condensate is discharged through multiple-port openings of a float-controlled rotary valve and continuous discharge is maintained at a rate determined by the height of condensate in the body. The bulletin contains data on capacities, dimensions and list prices.

Fuel Saving

A helpful 16-page brochure is being distributed by the Ohio Coal Association, Rockefeller Building, Cleveland, O., containing data on coal reserves and availability, transportation rates to various localities, coal characteristics, typical specifications and recommendations for different applications, as well as a discussion of how various factors affect performance. There are also sections on air pollution, ash collectors, over-fire air jets and coal storage.

Oil Burner

The Engineer Co., New York, has put out Drawing 2223-B with descriptive notes covering its wide-range mechanical atomizer with control for 8-to-1 capacity range. No returning or recirculating of hot oil is required and the high oil pressure employed over the entire load range insures efficient atomization at low load. The burner may be used with various types of registers.

Pressure Reducing Valves

Northern Equipment Co., Erie, Pa., has published a 12-page catalog dealing with its Copes pressure-reducing valves. This line comprises five self-contained pressure regulators, four different master pressure controls and three valves suited for remote

operation from masters. Each type is described and illustrated, and its application discussed. The catalog also includes information on the Copes desuperheater.

Rotameter

Schutte & Koerting Co., Philadelphia, has issued a 36-page bulletin, 18-R, covering "Rotameters," specific gravity indicators and flow indicators.

There is a section explaining Rotameters in general and their method of operation, mathematical formula for such operation being derived in another part of the bulletin. New tables permit easy selection of the correct Rotameter for a specific application, either fluid or gas.

Steel Analyses Chart

A revised Corrosion- and Heat-Resisting Steel Analyses Chart is being issued by Globe Steel Tubes Co., Milwaukee. The tabulation shows the chemical analysis of most of the stainless steels that are produced by the many steel mills.

New Equipment

The following illustration was inadvertently inserted in an item describing a liquid level alarm of the Reliance Gauge Column Co., Cleveland, in our April issue. Apologies are extended to both companies—EDITOR.

Regulating Valves

A new reversing superstructure for use on its diaphragm regulating valves has been introduced by Leslie Co., Lyndhurst, N. J., manufacturers of pressure and temperature regulators and controllers.

This new superstructure permits the reversing of the valve action by simple substitution for the standard superstructure, there being no need to remove the

valve body from the line. This can save much of the time ordinarily required to remove a diaphragm regulating valve from the pipe line, remove the old gaskets, scrape the faces of the flanges and invert the valve body. The standard characteristic valve action is maintained when changing from one superstructure to another.

Gas Turbine for Electric Utility

The first gas turbine for an electric utility in this country is under construction at the General Electric Company's Schenectady Works and will be shipped to the Southwest early in 1949. A duplicate of the 4800-hp locomotive gas turbine first announced in March and now undergoing tests, the 3500-kw turbine-generator set was purchased by the Oklahoma Gas and Electric Company, and will be installed at the Arthur S. Huey Station, Oklahoma City.

The new unit will be installed in an extension to the present station and operated on natural gas which is available in abundance in the area. The waste heat from the exhaust will be used with a separate heat-exchanger to supplement the present boiler feedwater heating system. This will result in additional kilowatt output.

The "straight-through" or in-line arrangement of the compressor, combustion chambers, and turbine was selected for this application. Because there are only two major moving parts, the turbine and compressor rotors, maintenance of the gas turbine is expected to be low.

The gas turbine will be geared to a conventional 3600-rpm totally enclosed generator with direct-connected exciter. The only water required in its operation will be a small quantity for cooling the bearing lubricating oil and for cooling the a-c generator.

Boiler Inspection to Meet in Boston

This year the National Board of Boiler and Pressure Vessel Inspectors is holding its Annual Meeting, May 24–27, at the Parker House in Boston, following a meeting of the A.S.M.E. Boiler Code Committee. The meeting also marks the Fortieth Anniversary of the boiler inspection law in the Commonwealth of Massachusetts.

The program includes numerous addresses, several dealing with histories and administrative experiences of the Massachusetts Code, the A.S.M.E. Boiler Code and the National Board, as well as with pressure vessel research. Several round table sessions are provided and the program will conclude with a banquet on Wednesday evening.

Spreader Stoker Conference

Representatives of eight spreader stoker manufacturers and Bituminous Coal Research, Inc., met on May 10 to study means for improving the utilization of bituminous coal. This meeting was brought about by the increasing acceptance of spreader-stoker firing in industrial and public utility plants and a desire to extend its versatility and overall efficiency.

A Spreader Stoker Research Committee was formed to administer the program. William S. Major, development engineer of Bituminous Coal Research, Inc., was elected chairman of the committee which is composed of two representatives from the bituminous coal industry, one from each of the cooperating spreader stoker manufacturers and two from Bituminous Coal Research, Inc.

REVIEW OF NEW BOOKS

Any of the books here reviewed may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Centrifugal and Axial Flow Pumps

By A. J. Stepanoff

In reviewing the first edition of a technical book it is desirable to mention the background of the author so that the reader may judge as to his qualifications. In this case the author, Dr. Stepanoff, is a development engineer of the Ingersoll-Rand Company in which capacity he has long been associated with centrifugal pump development and design. Moreover, he was recipient of the A.S.M.E. Melville Medal in 1932 and subsequently won three first prizes from the Hydraulic Institute.

The book, which deals with theory, design and application of centrifugal pumps, aims to bring the reader up to date as to progress in the design and construction of such equipment during recent years to meet new conditions of pressure, capacity, temperature, speed, etc.

The first few chapters review the basic theories and terminology, which is followed by a discussion of design factors for various types, special problems, performance, applications and operation. While the treatment in some respects is necessarily technical, it is by no means over the head of the average engineer.

There are 428 pages, 6 × 9 in., with cloth binding, and the price is $7.50.

Elementary Physical Metallurgy

By Edward G. Mahin

The author, who is professor of metallurgy and head of that department at the University of Notre Dame, has kept in mind the needs of beginners in the study of physical metallurgy, whether they be students or engineers seeking some knowledge of that subject. Hence special attention has been given to the explanation of fundamentals.

Starting with the microscope and the preparation of metallographic specimens, the text takes up properties of materials, their relationship to one another, methods of testing and interpretation of the results. Such subjects as hardness, thermal analysis, pyrometry, crystal, space, lattice and phase diagrams are discussed at length.

There are 276 pages, $5^1/_2$ × 9 in., cloth bound and adequately illustrated with reproductions of photomicrographs and diagrams. The price is $6.00.

Boiler Fireman's Handbook

By Joseph R. Darnell

As the title implies, this is a practical treatment of the many problems encountered in boiler plant operation, much of the subject matter having been published serially in *Power Plant Engineering* during the period 1944–1946.

An idea of the coverage may be had from a listing of the chapters which include: Fundamentals of Combustion; Why Flue Gas Temperature Goes Up When the CO_2 Goes Down; Sampling and Analyzing Flue Gas; Interpreting Flue Gas Analyses; Measuring Flue Gas and Furnace Temperatures; Coal Storage and Preparation for Use; Boiler Efficiency Calculations from Flue Gas Analysis and Temperature; Types of Air Preheaters and Effect of Preheated Air, Natural and Mechanical Draft; Draft Gages; Hand Firing Methods; Stoker Firing; Oil Firing; Gas Firing; Pulverized Coal Firing; Waste Fuels; Heating Feedwater; and Flexibility in Firing Equipment.

Obviously, in a book of less than 200 pages the foregoing wide range of subjects cannot be accorded detailed consideration, but it is believed that enough is given to provide the operating man an insight into many of the problems involved.

The book, attractively bound, is priced at $3.00.

Results of Publicly Owned Electric System

Have earlier edition

This is the Ninth Edition, published by Burns & McDonnell Engineering Company, consulting engineers of Kansas City, Mo., and Cleveland, O., who have long specialized in municipal power plant work.

The 384 pages are largely satistical, covering data on the physical plant, output, number of consumers, rates for electricity and earnings of 588 municipal plants out of a total of 859 at present serving communities of over 2500 population in the United States. Plants serving communities of less than 2500 are not included. Some information is also included on Federally-owned power systems.

The price, with plastic ring binding, is $10.

Synthetic Petroleum from the Synthine Process

By B. H. Weil and John C. Lane

In view of the current unprecedented demands for gasoline and light fuel oil, with further upward trend indicated, and the limited supply from natural sources, the synthetic production from coal or natural gas has become a very live subject upon which vast funds are now being spent for development. Therefore, the appearance of this book is most timely. The authors are, respectively, connected with the State Engineering Experiment Station of the Georgia School of Technology and the Gulf Research and Development Company.

The Synthine Process described in this book was originally developed in Germany over 20 yr ago as the Fischer-Tropsch process and was used commercially during the recent war. Drastic improvements have since been made in the process by chemists and engineers of the petroleum industry and the U. S. Bureau of Mines, and two plants are now being constructed by private groups in Texas and Kansas to produce gasoline, diesel fuels and chemicals from natural gas by this means.

The book contains over 300 pages, fully illustrated, and is priced at $6.75.

Jet Propulsion Progress

By Leslie E. Neville and N. F. Silsbee

Although this subject is removed from the stationary power plant field, it should hold interest for many COMBUSTION readers because of popular appeal at this time and the fact that it involves the gas turbine which is dealt with at some length. The text tells a fascinating story of the rapid advance in both jet propulsion and gas turbine development abroad and here, during and since the war; it also discusses problems still to be solved and affords a glimpse into the future. Despite the subject being technical, the treatment is largely nontechnical.

The price of this 232-page, cloth-bound book is $3.50.

Engine Room Questions and Answers, First Edition

By Alex Higgins

This is a companion book to the author's previously published volume on boiler room practice. Employing the "question-and-answer method" its principal purpose is to assist those preparing for an operator's license by acquainting them with the principles underlying the construction and operation of engine-room equipment. More than half the text is devoted to steam engines of various types, and the remainder to steam turbines, condensers, bearings and lubrication.

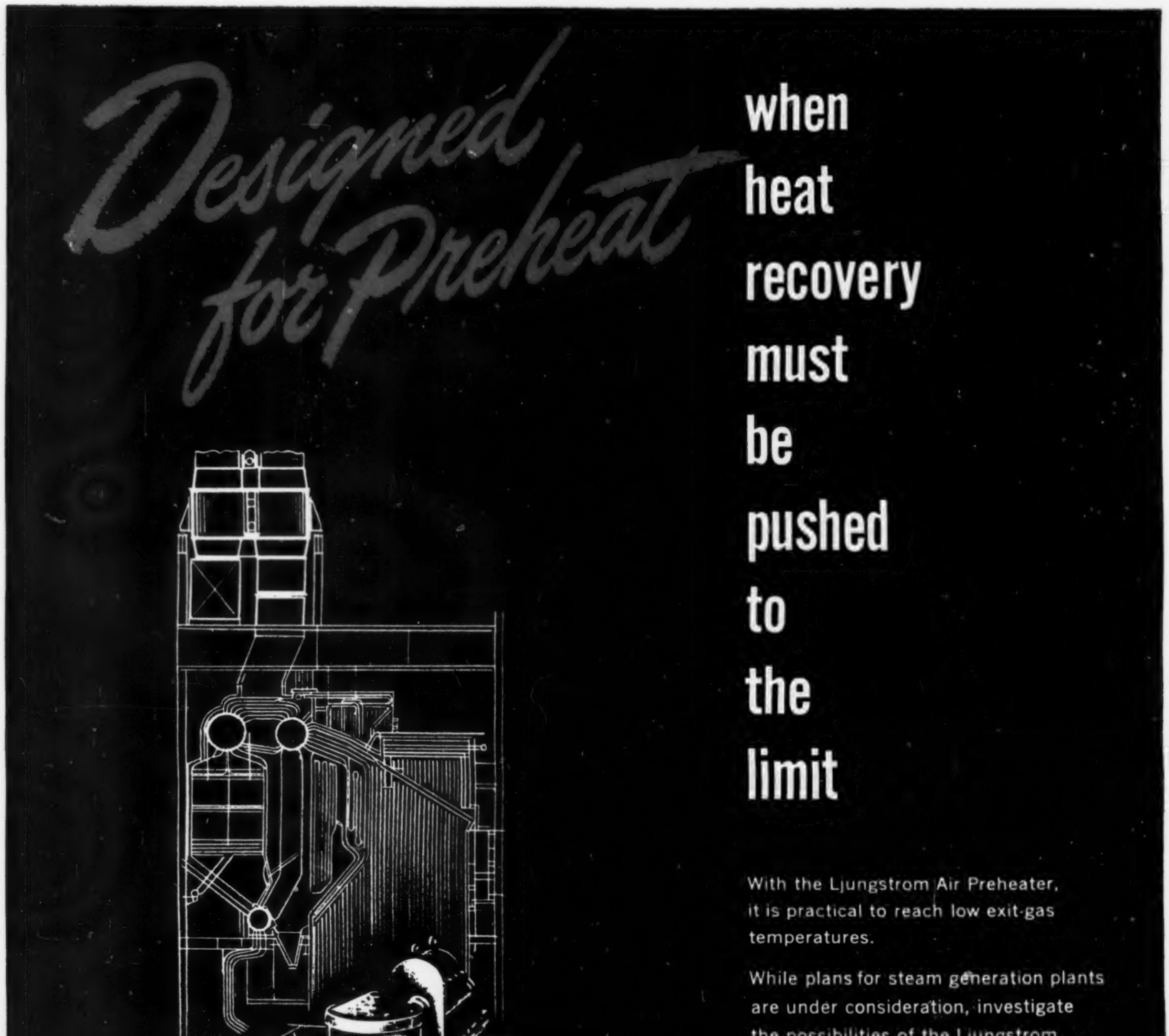
There are 154 pages and their size, 9 × 11 in., makes it possible to read easily the illustrations showing details. The price is $4.00.

Supercharging the Internal-Combustion Engine

By E. T. Vincent

This represents a technical treatise combined with descriptive matter, a certain amount of design information, and performance data. The text is based largely on notes employed by Professor Vincent in a government-sponsored course on superchargers during the war. Chapters deal with historical development, thermodynamics, the engine cycle, types of compressors, the impeller and diffuser, estimating operating conditions, surging in centrifugal compressors, turbo-supercharging, the axial-flow compressor, and the supercharged diesel cycle.

There are 315 pages, 6 × 9 in., fully illustrated and cloth bound. The price is $5.00.


Designed for Preheat
when heat recovery must be pushed to the limit
With the Ljungstrom Air Preheater, it is practical to reach low exit-gas temperatures.
While plans for steam generation plants are under consideration, investigate the possibilities of the Ljungstrom. The specialized experience of Air Preheater engineers is at your disposal, to aid in effecting the most economic heat recovery from flue gases.
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